Implementation of Fisheries Enhancement Opportunities on the Coeur d'Alene Reservation

Research, Monitoring, and Evaluation Report

BPA Project # 1990-044-00

Report covers work performed under BPA contract #(s) 76243, 76828 REL 1, 76828 REL 4

Report was completed under BPA contract #(s) 76828 REL 4

1/1/2018 – 12/31/2019

Firehammer, J. A. and A. J. Vitale

Coeur d'Alene Tribe, Plummer, ID, 83851

01 – 2020

This report was funded by the Bonneville Power Administration (BPA), U.S. Department of Energy, as part of BPA's program to protect, mitigate, and enhance fish and wildlife affected by the development and operation of hydroelectric facilities on the Columbia River and its tributaries. The views in this report are the author's and do not necessarily represent the views of BPA.

This report should be cited as follows:

Firehammer, J. A. and A. J. Vitale. 2020. Implementation of Fisheries Enhancement Opportunities on the Coeur d'Alene Reservation: Research, Monitoring, and Evaluation Report, 1/1/2018 – 12/31/2019 Annual Report, Project #1990-044-00.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF PHOTOS

ABSTRACT

Non-native fish suppression measures have been implemented in the Coeur d'Alene Basin over the past fifteen years as part of an overall habitat restoration strategy administered and executed by the Coeur d'Alene Tribe's Fisheries Program to recover native populations of westslope cutthroat trout (WCT) to sustainable, harvestable levels. In the upper Benewah watershed, a localized brook trout suppression program, which commenced in 2004, has kept the population at a depressed manageable level. The number of age one and older brook trout removed in each of 2018 and 2019 was less than 30, representing the lowest documented over the course of the program, and densities of this age class have virtually been maintained at levels below 3 fish/100 m in mainstem habitats since 2011, which is ten times lower than when the suppression program began. Moreover, annual removal efforts since 2011 have required only 2-4 days compared with the 3-4 weeks that were initially invested. Age one and older brook trout have also been essentially regulated at densities less than 3 fish/100 m in untreated reaches of proximate sub-drainages since 2011, a value almost three times less than the average observed throughout the early years of the program. Coincident with the decline in brook trout, WCT currently comprise over 80% of the salmonid assemblage in downstream reaches of these sub-drainages. In the lower Evans Creek watershed, where suppression efforts have been ongoing since 2017, approximately 100 age one and older brook trout were removed in each of 2018 and 2019, representing a density of over 6 fish/100 m. The number of age-0 fish removed in 2019, however, exceeded 760 which represented a three-fold increase in this age-class over the previous year. Additional suppression tactics, similar to those that have been employed in the Benewah watershed, need to be introduced into Evans creek to curb such levels of reproduction.

Adfluvial WCT originating from the Lake Creek watershed have responded favorably to the northern pike suppression efforts that have been implemented in Windy Bay of Coeur d'Alene Lake since 2015. Juvenile outmigrants have returned to spawn at rates four times greater than those recorded over a ten year period prior to program implementation. In addition, approximately 500 spawners were estimated to have ascended Lake Creek in 2019, a most certain result of the increase in survival of WCT during lake residence that was documented by the tagged outmigrants. Furthermore, the 2019 adult abundance estimate was twice that obtained in 2018, and the largest estimate recorded over the migrant trapping program. Though the number of pike removed from Windy Bay declined by over 80% from 2015 to 2018, a total of 338 pike was captured in gillnets deployed during the spring of 2019, which exceeded the number removed in the first year of suppression. Moreover, almost 90% of the fish removed in the spring of 2019 were less than 600 mm, reflecting a young age distribution. The results observed allude to a compensatory response in young recruits due to the reduction of competition and cannibalism from the annual removal of larger pike. Consequently, suppression strategies have been modified in Windy Bay to introduce supplemental netting during both spring and fall periods to more effectively control pike numbers.

Northern pike suppression efforts were introduced across the southern end of Coeur d'Alene Lake in 2019. A combination of exploratory netting and radio-telemetry revealed that spawning aggregations of pike were more widespread in the southern end than in Windy Bay, which will require a greater degree of logistical support when implementing concerted removal efforts. Conversely, during the fall pike were infrequently captured in those shallow habitats where they were found aggregated in the spring, and were most heavily concentrated in deeper waters of Benewah and Chatcolet lakes. Given that concentrations of pike were limited to fewer areas in

the fall than in the spring, fall suppression may be equally or more effective than spring efforts in depleting this population. Experimental deployments found that nets with smaller mesh sizes captured almost twice as many pike, but captured other large-bodied species at lesser rates, than large mesh nets, which will decrease the incidence of bycatch mortality and increase the overall effectiveness of the suppression program. In 2019, a total of 1409 pike were removed in the southern end, representing approximately 50-60% of available population estimates. More effort, however, will need to be devoted in subsequent years to sufficiently depress pike numbers as catch rates of pike in 2019 did not decline over time signaling a lack of measurable population depletion. In addition, spawning habitats outside of the targeted suppression area were identified using radio-telemetry in 2019, suggesting that some pike may not be susceptible to removal tactics in the spring. Plans are currently being developed to modify these apparent centers of pike production to limit their accessibility to migratory adults, and to conduct additional research to better understand the variability of life-history strategies in this population.

In the past, monitoring efforts for WCT have primarily focused on assessing the status and trend of populations at the watershed scale to identify primary factors limiting population recovery, and tracking the status and trend of sub-populations at smaller, sub-drainage scales to identify impairments in stream habitat for the prioritization of localized restoration efforts. More recently, however, monitoring actions are serving in analyses to evaluate the effectiveness of non-native fish suppression measures. Migrant traps will continue to be used as the preferred method to evaluate the numerical response of adfluvial WCT in the Lake and Benewah creek watersheds to pike suppression, for estimates generated from both adult and juvenile traps are invaluable when interpreting population trajectories. Summer stream surveys will still be periodically conducted in both Benewah and Evans creeks to evaluate the overall change in WCT density across untreated reaches to the removal of brook trout in downstream habitats. In the upper Benewah watershed, stream surveys will also be used to evaluate how pike suppression improves the resiliency of sub-drainages to periodic severe water years that impact WCT during stream residence. Surveys conducted in 2018 in the Windfall sub-drainage indicated that WCT have not yet fully recovered from the extreme hydrologic conditions that developed in 2015; WCT densities averaged only 46% of their peak value generated from earlier years. The annual removal of pike in the southern end of the lake is expected to recover the depressed status of the WCT population in Benewah Creek, and provide an abundant ‘reserve’ of adults in the lake that could re-populate a predominantly adfluvial sub-drainage like Windfall Creek.

PIT-tag technology has been used to describe the spatial distribution of the adfluvial life-history form in the Lake and Benewah creek watersheds, and to illustrate movements and growth rates of out-migrating juvenile WCT that allude to important seasonal spring habitats that can be reproduced with habitat restoration actions. Currently, it is being used to evaluate actions aimed at re-establishing the migratory component in sub-drainages in which the variant is seemingly deficient. In the upper Lake creek watershed, monitoring efforts have consistently found adfluvial adults to ascend the Bozard sub-drainage over six times more often than the upper fork of Lake Creek, and juvenile adfluvial indices generated in the upper fork of Lake Creek during this reporting period were 2 to 3.5 times lower than what is typically observed in the Bozard sub-drainage. Given that a putative barrier to adfluvial production was addressed in the upper fork of Lake Creek in 2018, these metrics that illustrate the prevalence of the adfluvial variant will be tracked over time to evaluate the rate of its re-colonization in the upper fork of Lake Creek.

1.0 INTRODUCTION

1.1 Project background

Traditionally, the Coeur d'Alene Indian Tribe depended on runs of anadromous salmon and steelhead along the Spokane River and Hangman Creek, and at usual and accustomed fishing sites on the Columbia River and south in the Clearwater River drainage, as well as resident and adfluvial forms of westslope cutthroat trout (*Oncorhynchus clarki lewisi*) and bull trout (*Salvelinus confluentus*) in the Coeur d'Alene basin for subsistence. Dams constructed in the early 1900s on the Spokane River in the City of Spokane and at Little Falls further downstream were the first dams that inhibited the ascension of anadromous fish. Anadromous runs were then completely extirpated from the Tribe's territories upon construction of Chief Joseph and Grand Coulee Dams on the Columbia River, and Dworshak Dam on the North Fork Clearwater River. Collectively, these actions forced the Tribe to rely on the fish resources of Coeur d'Alene Lake for their subsistence needs.

Historically, the Coeur d'Alene Tribe is estimated to have annually harvested around 42,000 westslope cutthroat trout (WCT) from the Coeur d'Alene basin (Scholz et al. 1985). Today, however, only limited harvest opportunities exist for WCT due to a suite of factors within the basin that have contributed to their decline. These factors include the construction of Post Falls Dam in 1906, changes in land cover types, impacts from agricultural activities, and introduction of exotic fish species (Mallet 1969; Scholz et al. 1985; Lillengreen et al. 1993). The depressed status of WCT in the basin has been a concern of Coeur d'Alene Tribe's Fisheries and Water Resources programs since 1990 and has prompted efforts to support their recovery. Overarching recovery goals have been to restore populations to levels that allow for subsistence harvest, maintain genetic diversity, and increase the probability of persistence in the face of anthropogenic influences and prospective climate change. This included recovering the lacustrine-adfluvial life history form that was historically prevalent and had served to provide resiliency to the population structure in the Coeur d'Alene basin.

Achieving sustainable WCT populations required addressing biotic factors and habitat features in the basin that were limiting recovery. From 1990 to 1994, BPA-funded surveys within reservation watersheds were conducted that identified various limiting factors, which included low-quality, low-complexity rearing habitats and riparian zones, high stream temperatures, negative interactions with nonnative brook trout *(Salvelinus fontinalis)* in stream habitats, and potential survival bottlenecks in Coeur d'Alene Lake. In 1994, the Northwest Power Planning Council adopted recommendations set forth by the Coeur d'Alene Tribe that would address these factors to support the recovery of WCT populations and the re-establishment of a fishery (NWPPC Program Measures 10.8B.20).

Accordingly, the BPA project entitled "Implementation of Fisheries Enhancement Opportunities on the Coeur d'Alene Reservation" (#1990-044-00), which is sponsored and implemented by the Coeur d'Alene Tribe Fisheries Program, has supported the various recovery measures, which have included habitat enhancement and restoration actions, non-native biological control, and research, monitoring and evaluation (RME) activities that would inform future management decisions. This annual report summarizes RME data collected from 2018 to 2019 to fulfill the contractual obligations for this BPA project, and also includes data from past reporting periods to better describe trends in biological response variables.

1.2 Study area

The study area addressed by this report consists of the southern portion of Coeur d'Alene Lake and four low-elevation watersheds – Alder, Benewah, Evans, and Lake - which lie within the Coeur d'Alene sub-basin (Figure 1). The Coeur d'Alene sub-basin is approximately 9,946 square kilometers and extends from Coeur d'Alene Lake upstream to the Bitterroot Divide along the Idaho-Montana border. Elevations range from 646 meters at the lake to over 2,130 meters along the divide. Coeur d'Alene Lake, the principle water body in the sub-basin, is the second largest in Idaho and is located in the northern panhandle section of the state. The lake lies in a naturally dammed river valley with the outflow currently controlled by Post Falls Dam. The lake covers 129 square kilometers at full pool with a mean depth of 22 meters and a maximum depth of 63.7 meters. This area formed the heart of the Coeur d'Alene Tribe's aboriginal territory, and a portion of the sub-basin lies within the current boundaries of the Coeur d'Alene Indian Reservation (Figure 1).

The four watersheds currently targeted by the Tribe for restoration are located mostly on the Reservation (Figure 1), but cross boundaries of ownership and jurisdiction, and have a combined basin area of 34,853 hectares that include 529 kilometers of intermittent and perennial stream channels. The climate and hydrology of the target watersheds are similar in that they are influenced by the maritime air masses from the pacific coast, which are modified by continental air masses from Canada. Summers are mild and relatively dry, while fall, winter, and spring bring abundant moisture in the form of both rain and snow. A seasonal snowpack generally covers the landscape at elevations above 1,372 meters from late November to May. Snowpack between elevations of 915 and 1,372 meters falls within the "rain-on-snow zone" and may accumulate and deplete several times during a given winter due to mild storms (US Forest Service 1998). The precipitation that often accompanies these mild storms is added directly to the runoff, since the soils are either saturated or frozen, causing significant flooding.

1.3 Research, monitoring, and evaluation objectives

Objective 1: Evaluate the effectiveness of non-native fish suppression measures

Brook trout suppression programs were initiated in the upper Benewah watershed in 2004 and in the lower Evans watershed in 2017 given that this non-native species has been shown to negatively impact cutthroat trout when populations of the two overlap (Griffith 1988; Peterson and Fausch 2003; Peterson et al. 2004; Shepard 2004). However, our approach did not entail chemical treatments and barrier installation to prevent re-colonization because connectivity with the lake was desired to promote the migratory life-history strategy of WCT, and our program deemed that the benefits of the expression of the adfluvial variant greatly outweighed the benefits of brook trout eradication in isolated tributaries (Peterson et al. 2008). Our suppression strategy entails annually removing fish before fall spawning periods and installing temporary barriers to impede access to spawning habitat. Monitoring the success of the removal program is conducted by examining changes in metrics of brook trout and WCT abundance in index reaches in each watershed.

Prior monitoring efforts in Lake and Benewah creeks have indicated that juvenile to adult return rates for migratory WCT were eight to ten times lower than those reported in other adfluvial systems (Gresswell et al. 1994; Huston et al. 1984). Further, survival rates during lake residence have been considered a key vital rate in influencing population trajectories of adfluvial cutthroat trout (Stapp and Hayward 2002). These results prompted a research study, conducted from 2011 to 2013, into the demographics and dietary preferences of northern pike (*Esox lucius*), a non-native species introduced into the Coeur d'Alene basin approximately forty years ago. Study results found WCT to be a primary dietary item of pike, and also demonstrated using bioenergetics modeling that pike could annually consume approximately 50% of spawners destined for area streams (Walrath et al. 2015a). Consequently, aggressive pike suppression measures were deemed necessary to recover adfluvial WCT populations in the basin. Accordingly, a suppression program was initiated in 2015 in Windy Bay, the bay into which Lake Creek enters, to evaluate whether such a localized effort would increase survival rates of Lake Creek WCT. In 2019, the suppression program was expanded to include the southern end of Lake Coeur d'Alene to benefit migratory salmonids (e.g., WCT originating from Benewah Creek) that utilize this area of the lake as a migratory corridor or temporary rearing habitat.

Objective 2: Describe the status and trend of WCT in Lake and Benewah creek watersheds

Status and trend monitoring is conducted at the watershed scale by generating annual estimates of adfluvial spawners and juvenile outmigrants that serve to describe trajectories in adfluvial production and aid in the assessment of population responses to collective habitat restoration efforts (Bradford et al. 2005). Survival rates of both life stages are also assessed annually at the watershed scale to evaluate population response to northern pike suppression measures. Monitoring is also conducted at the sub-drainage and reach scales in both watersheds to describe the spatial distribution of WCT during summer rearing periods which permits an examination of whether abundance trajectories differ across sub-drainages or reaches within sub-drainages. The detection of declining trends or persistently low numbers of fish at these scales may signal localized degradation or deficiencies in habitat conditions that need to be addressed and prioritized for prospective habitat improvements. The spatial distribution of the adfluvial life-history variant is also assessed at the sub-drainage scale to examine potential impediments to adfluvial production and to prioritize future restoration efforts for either the preservation or re-establishment of the migratory life-history strategy.

2.0 METHODS

2.1 Non-native fish suppression

Brook trout suppression

In the upper Benewah watershed, single-pass electrofishing was used in late summer to remove brook trout from two river kilometers (rkm) of mainstem reach from 12-mile bridge to the confluence of West Fork Benewah (WFB) and South Fork Benewah (SFB) creeks (rkm 19.8-21.8). In addition, temporary barriers were installed immediately upriver of 12-mile bridge and at the mouth of Windfall Creek (Benewah rkm 19.3) to prevent access to upriver habitat. Trends in brook trout removed from the 2 km index reach, a reach that has been consistently addressed since 2005, were examined to evaluate the response of brook trout to the suppression program. Trout response was also evaluated by examining the trend in mean density indices of age 1+ brook trout and WCT calculated across index reaches in sub-drainages of the upper Benewah watershed proximate to the 2 km mainstem reach that have been regularly sampled since 2004. In the lower Evans watershed, single-pass electrofishing was used in late summer to remove brook trout from 1.6 km of mainstem reach (rkm 0.6-2.2) where high densities of both age-0 and older brook trout have been found. Trends in the numbers of brook trout removed from this index reach since 2017 were used to inform future suppression measures.

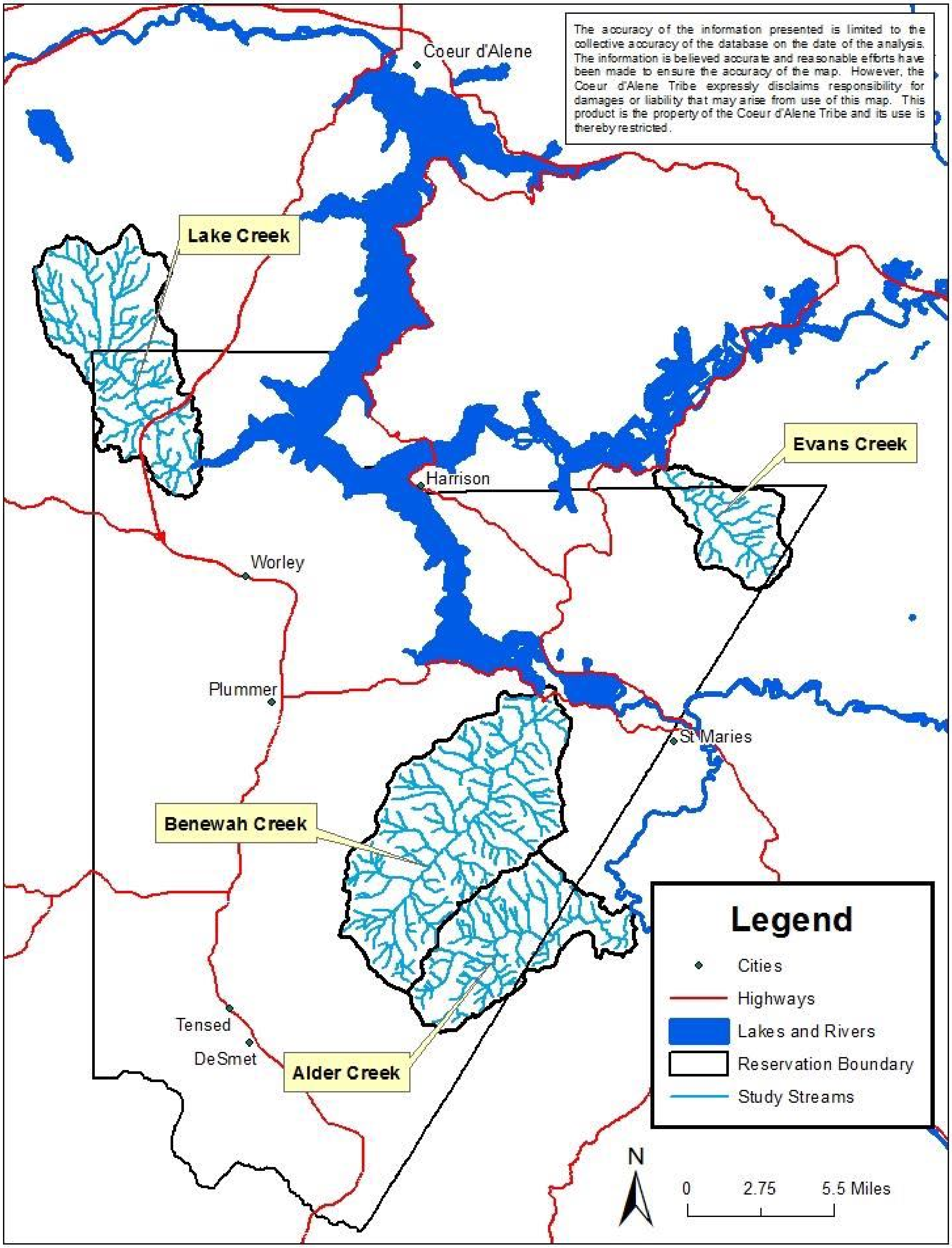


Figure 1. Focal watersheds in the Coeur d'Alene Basin targeted by BPA project 1990-044-00.

Northern pike suppression

Northern pike were removed from Windy Bay and the southern end of Lake Coeur d'Alene by deploying sinking gillnets (45.7 m long by 1.8 m deep) during periods when pike were highly vulnerable to capture. Suppression occurred in the spring after ice receded from the bay, when pike were found in shallow water spawning aggregations, and also during cool water periods in the fall (i.e., October-November), when pike were found to be active in shallow shoreline habitats. Nets were deployed overnight, were oriented perpendicularly from the shoreline, and deployed only during the work week to minimize interactions with anglers. In the spring, suppression efforts were terminated by the Memorial Day weekend or when northern pike were consistently captured at a low rate, indicating a combination of their depletion and the dispersal of remaining individuals to deeper waters. In the fall, suppression efforts were also discontinued if northern pike were captured at low rates or if lake conditions precluded effective netting.

In Windy Bay during both spring and fall suppression periods, variable mesh nets (three 15.2 m panels of 3.8, 4.4, and 5.1 cm bar mesh) were deployed daily at eight locations selected from a set of twenty-four waypoints situated around the mouth of Lake Creek and spaced at 200 m intervals using a stratified-random approach (Figure 2). In the southern end of the lake, spring suppression comprised daily deployments of four to eight nets in areas that targeted spawning aggregations. Equivalent numbers of variable mesh nets and 5.1 cm bar mesh (i.e., large mesh) nets were deployed simultaneously to evaluate differences in catch rates for select species. Fall suppression in the southern end comprised only variable mesh nets and initially entailed systematically sampling every 4th waypoint from a set situated around the shoreline perimeter and spaced at 200 m intervals (Figure 2). Additional fall suppression efforts in the southern end targeted areas where northern pike were concentrated.

All species captured in gillnets were tallied and their fate recorded to evaluate species composition and mortality rates. The total length of all northern pike captured was recorded to evaluate temporal changes in the size distribution of fish removed. In Windy Bay, numbers of pike annually removed and return rates of WCT tagged in Lake Creek migrant traps served to evaluate the response to the suppression program. In the southern end of the lake, data collected from the fall systematic sampling will be used in a power analysis to evaluate the number of nets required to be deployed annually in index areas to track trends in catch rates of northern pike.

In the fall of 2018, northern pike captured using short duration gillnet deployments were implanted with radio-tags in the southern end of Lake Coeur d'Alene. Exploratory gillnetting was first conducted across the southern end to determine areas where pike were most heavily concentrated to allocate tags accordingly. Tagged fish were tracked weekly by truck around the lake's southern perimeter in the winter, and by truck and boat in the spring to evaluate their movements and spatial distribution during seasonal periods. Data collected during tracking events were used to target removal efforts and to inform future suppression measures.

2.2 Status and trend of westslope cutthroat trout populations

Abundance and productivity of cutthroat trout at the watershed scale

Migrant traps, located downriver of primary spawning tributaries, were installed at rkm 7.2 in Lake Creek (Figure 3) and at rkm 14.0 (i.e., 9-mile) in Benewah Creek (Figure 4) during the spring to capture adfluvial WCT. Floating weir traps were used to intercept ascending and descending adults (Photo 1), and rotary screw traps were used to capture juvenile outmigrants

(Photo 2). Half-duplex (HDX) antennas spanning the stream were located in close proximity to adult traps in both watersheds to interrogate ascending adults that had been PIT-tagged in prior years. Interrogations from this reporting period and from prior reporting years served to generate estimates of return rates for juveniles and adults tagged since 2005.

Total length (TL, mm) and weight (Wt, g) were recorded from all adults. Ascending adults received an opercle punch, and those lacking a tag received an HDX PIT-tag intramuscularly near the pelvic fin. Opercle punches served to evaluate tag retention and generate abundance estimates (Chapman 1951; Appendix A). Total length was collected from all juveniles, with weights collected from fish that received intraperitoneal PIT-tags. Adipose fins were clipped on tagged fish for identification in recapture events and to assess tag retention. Fish were typically tagged every 2-4 days and used in trap efficiency trials to generate outmigrant abundance estimates (Carlson et al. 1998; Appendix A).

Abundance, distribution, and life-history diversity of cutthroat trout at sub-drainage scales

Electrofishing surveys were conducted during the summer at sites distributed across reaches in principal rearing sub-drainages of Lake Creek (Figure 3) and Benewah Creek (Figure 4) watersheds to describe the distribution and abundance of WCT. In the WFB, SFB, and Windfall sub-drainages of the Benewah Creek watershed, sites were selected using a stratified-randomized approach. Coarse-scale geomorphological features (e.g., land use, valley width, elevation, and channel gradient) were used to partition sub-drainages into 3-4 contiguous reaches (Figure 4), and two to four 100 m sites were randomly selected within each reach, with more sites generally assigned to longer reaches. In the upper fork of Lake Creek (UFL) sub-drainage in the Lake Creek watershed and in the Schoolhouse sub-drainage in the Benewah Creek watershed, established index sites were surveyed, with site lengths typically ranging from 75 to 100 m.

Electrofishing procedures used straight DC current and 300-400 volts of output, and block nets were placed at site boundaries to prevent immigration and emigration during sampling. Captured trout were enumerated, measured for total length, and weighed. In the UFL sub-drainage, fish longer than 75 mm received intraperitoneal PIT tags. Length distributions were examined to classify individuals as either young-of-the-year (age-0) or older fish (age 1+). Site abundances for age 1+ fish were indexed using first pass catch, and converted to densities (fish/100 m) to standardize comparisons. In the WFB, SFB, and Windfall sub-drainages, mean densities were generated for each reach and averaged across all reaches to yield overall estimates, whereas densities at index sites were averaged to yield an estimate for the Schoolhouse sub-drainage.

Interrogation data collected at fixed HDX directional PIT-tag arrays were summarized to describe the spatial distribution of the adfluvial life-history variant in the Lake Creek watershed. Arrays were installed at the mouths of the UFL, the West Fork of Lake Creek (WFL), and Bozard Creek, the three primary spawning and rearing sub-drainages, and at rkm 7.8 which is located 500 m upstream of the screw trap (Figure 3). Detection efficiencies at passive interrogation sites were generally high throughout the reporting period, yielding confidence in the conclusions drawn (Table B-1). The percentage of juveniles tagged at sites during summer stream surveys that were found to outmigrate the following spring was multiplied by their respective sites' densities to generate adfluvial indices. Adfluvial indices were then averaged across sites within sub-drainages of the Lake Creek watershed to permit comparisons.

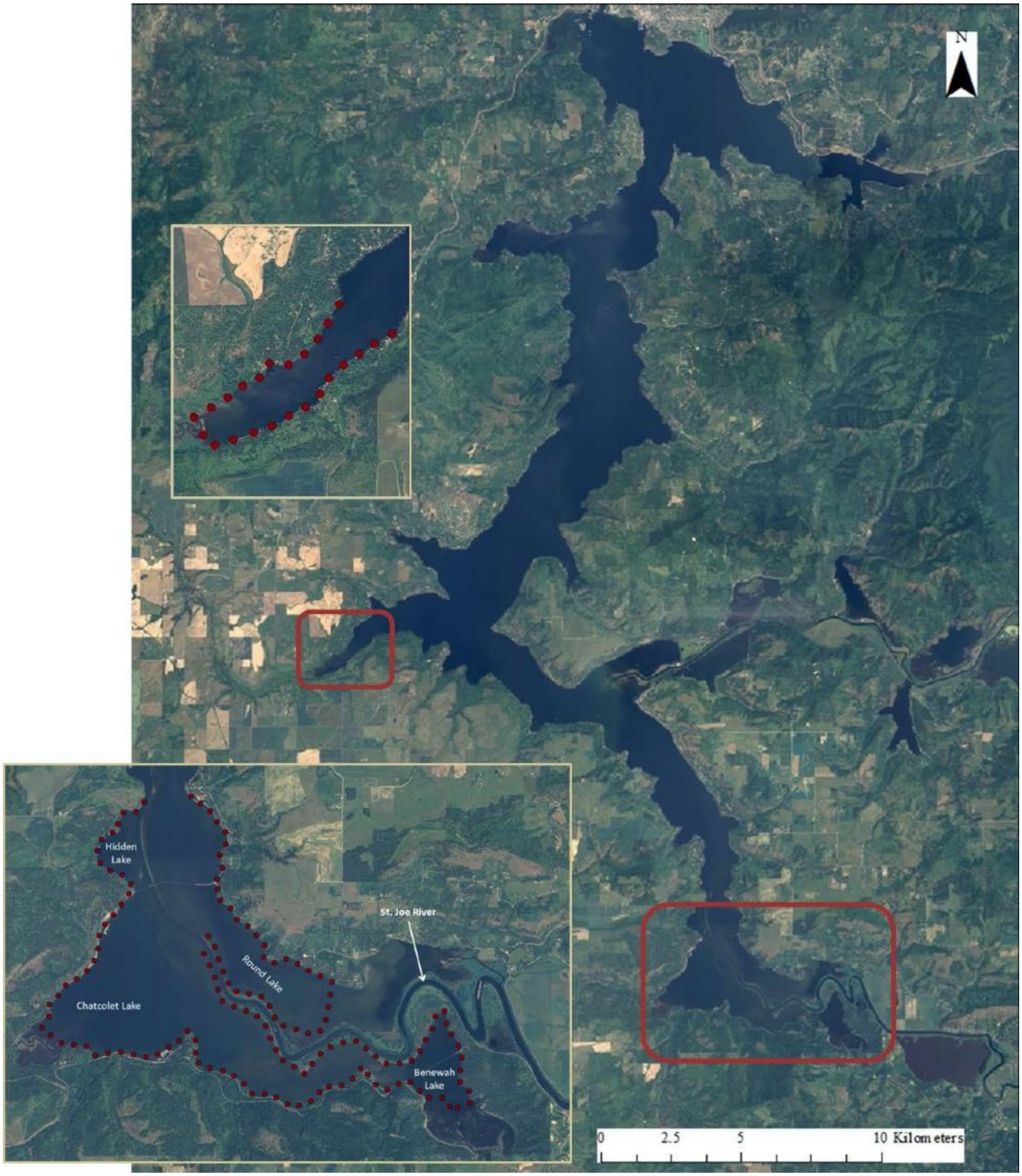


Figure 2. Locations of waypoints in Windy Bay (upper left corner) and the southern end of Coeur d'Alene Lake that were selected for northern pike suppression efforts.

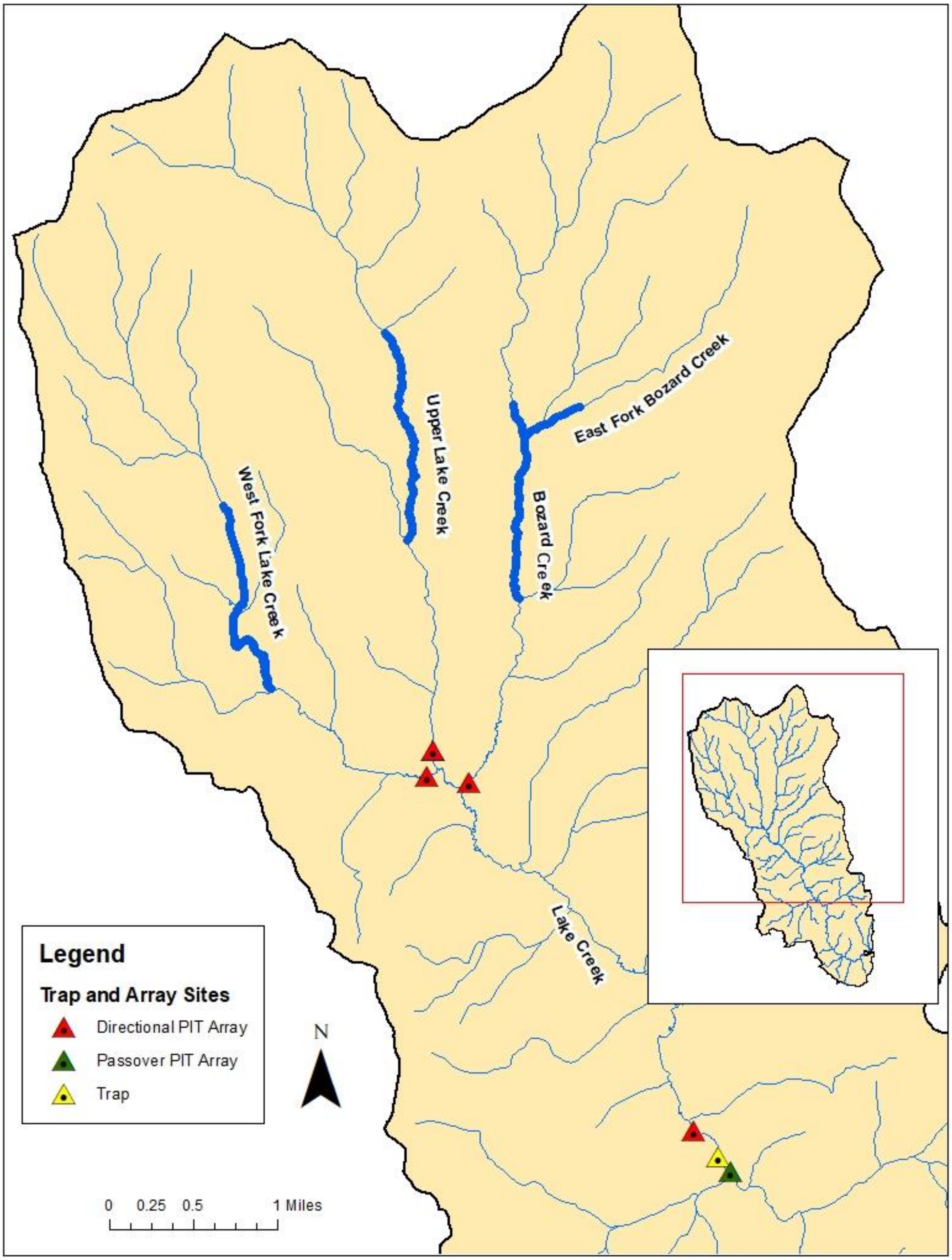


Figure 3. Highlighted reaches of sub-drainages in the Lake Creek watershed that were surveyed for WCT abundance and distribution or identified during prior reporting periods as core areas of adfluvial production. Locations of fixed PIT interrogation stations and migrant traps are also displayed.

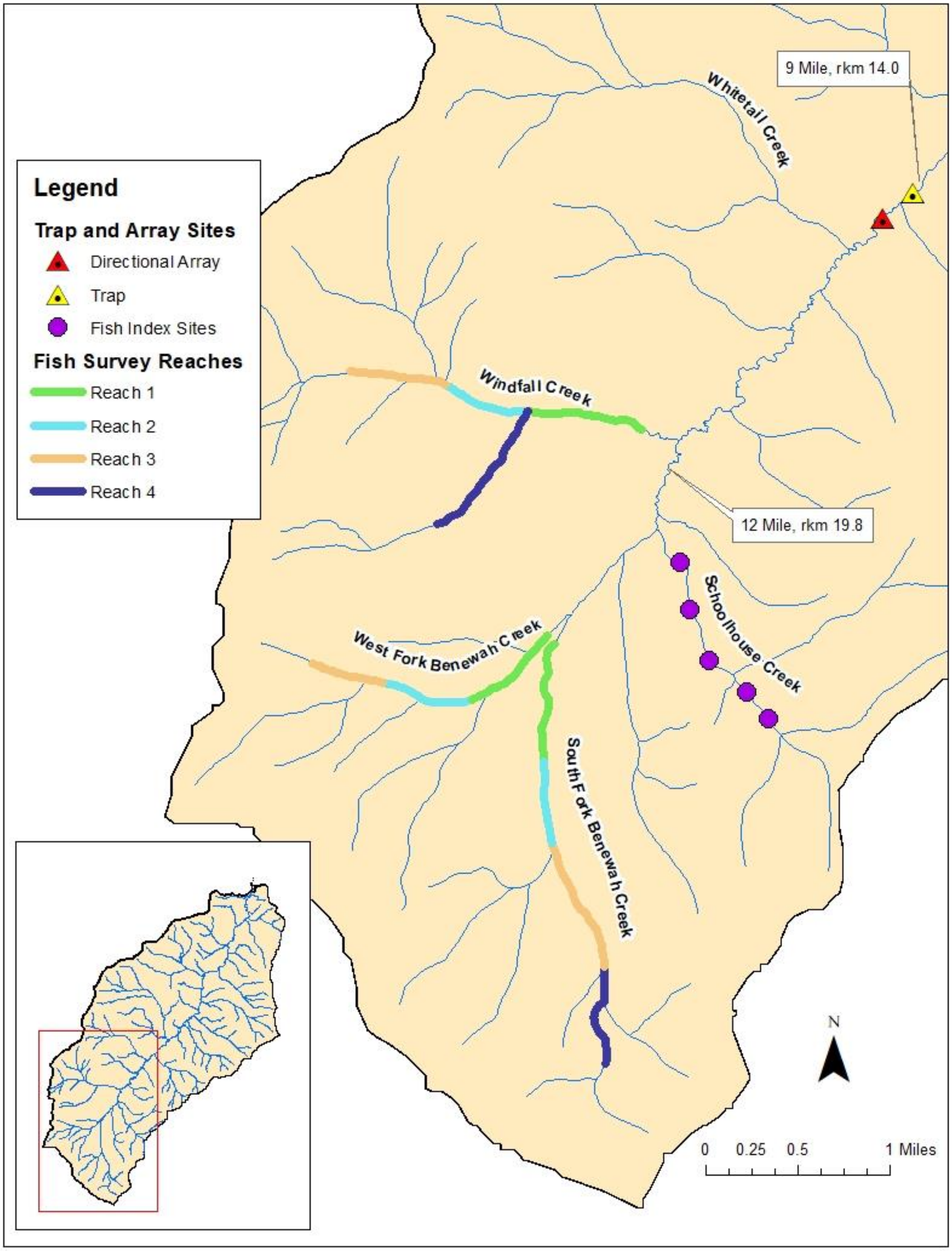


Figure 4. Locations of sites and reaches surveyed for WCT abundance and distribution in sub-drainages of the upper Benewah Creek watershed. Locations of fixed PIT interrogation stations and migrant traps are also displayed.

3.0 RESULTS

3.1 Effectiveness monitoring of non-native fish suppression

Responses to brook trout suppression efforts

In the upper Benewah Creek watershed, a total of 127 and 48 brook trout were removed from the 2.0 km mainstem index reach over three days of suppression effort in each of 2018 and 2019, respectively. The number of age 1+ fish annually removed from the index reach in each of the last two years was less than 30 and was the lowest observed over the course of the suppression program (Figure 5). Since 2011, the average density of age 1+ brook trout in the index reach has been 3.5 fish/100 m (2.9 when excluding the 2014 suppression year), which was three times lower than the average density of 10.5 computed from 2007 to 2010, and ten times less than the average density of 32.8 calculated over the first two years of the program. Though the annual number of age-0 brook trout removed from this reach has been generally more variable than older fish, with periodic upsurges in production, age-0 fish were kept in check over the last two years (Figure 5).

In sub-drainages of the upper Benewah watershed, a declining trend in the mean density index of age 1+ brook trout has been observed over the suppression program (Figure 6). Since 2011, densities in six of the seven years have averaged 2.8 fish/100 m, which is approximately three times lower than the average density of 7.7 fish/100 m calculated from 2004 to 2010. Incidentally, the mean density of 2.3 fish/100 m recorded in 2018 was one of the lowest values documented since program inception. Notably, periodic spikes in the mean density index in sub-drainage reaches have corresponded with increases in age-0 production documented in mainstem reaches the prior year. Converse to the brook trout trend, the mean percentage of WCT as overall salmonid catch has increased over time in sub-drainages (Figure 6). From 2004 to 2010, WCT constituted on average 66% of captured salmonids, whereas since 2011 they typically have comprised over 80% of the catch.

In the lower Evans Creek watershed, 353 brook trout were removed from the 1.6 km mainstem index reach over three days of effort in 2018, and 883 were removed from the index reach over two days of effort in 2019. The number of age 1+ fish removed across the index reach averaged 108 fish over the last two years, which was slightly lower than that removed in 2017. However, though the number of age-0 fish removed from this reach slightly declined from 2017 to 2018, over 760 fish were removed in 2019, representing a three-fold increase in production (Figure 5).

Responses to northern pike suppression efforts

During spring suppression efforts in Windy Bay, a total of 158 nets were deployed in 2018 and 59 northern pike were captured. Suppression commenced on March 13, though was temporarily suspended soon after for two weeks due to the presence and excessive capture of staging adult WCT. Throughout the spring until May 3 when suppression was terminated, daily catch rates of pike were not found to exceed 1.0 fish/net (Figure 7). In 2019, a total of 149 nets were deployed in the spring in which 338 pike were captured. Because of the prolonged presence of ice on the lake, suppression did not commence until April 9 upon which pike catch rates averaged 5 fish/net during the first three days of deployment (Figure 7). Thereafter, catch rates generally declined over the next month to levels less than 1 fish/net by early May. However, two weeks later catch rates approached or exceeded 2 fish/net in three of the four final deployments prior to termination of suppression efforts (Figure 7).

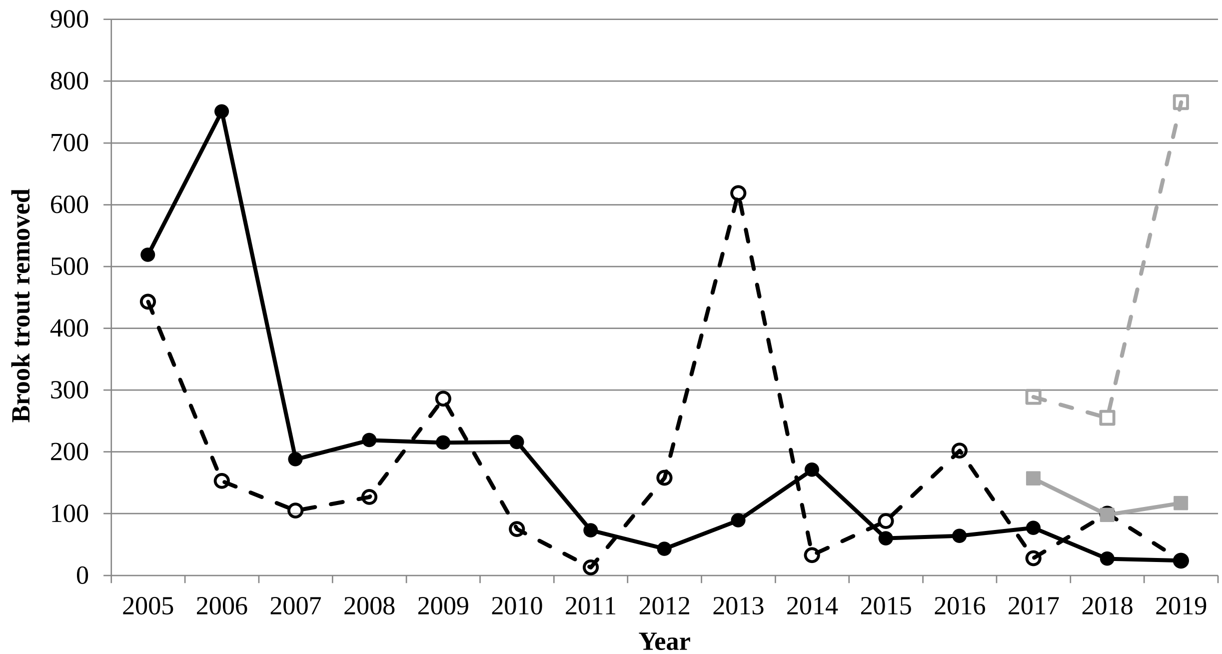


Figure 5. Numbers of age 1+ (solid line) and age-0 (dotted line) brook trout removed from the 2.0 km Benewah mainstem index reach (black) and the 1.6 km Evans mainstem index reach (grey), 2005-2019.

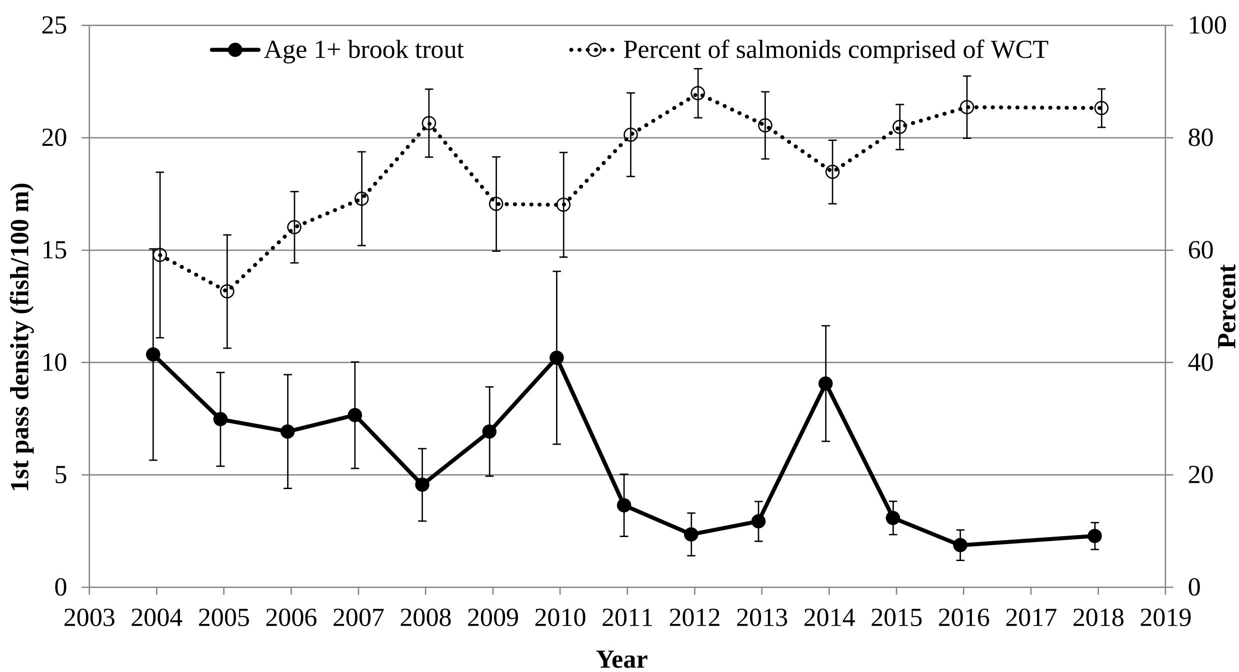


Figure 6. Mean density indices of age 1+ brook trout (1st pass catch/100 m) and percent of cutthroat trout as overall salmonid catch (± one standard error) across sites in sub-drainages of the upper Benewah watershed that have been regularly sampled over the years 2004-2018.

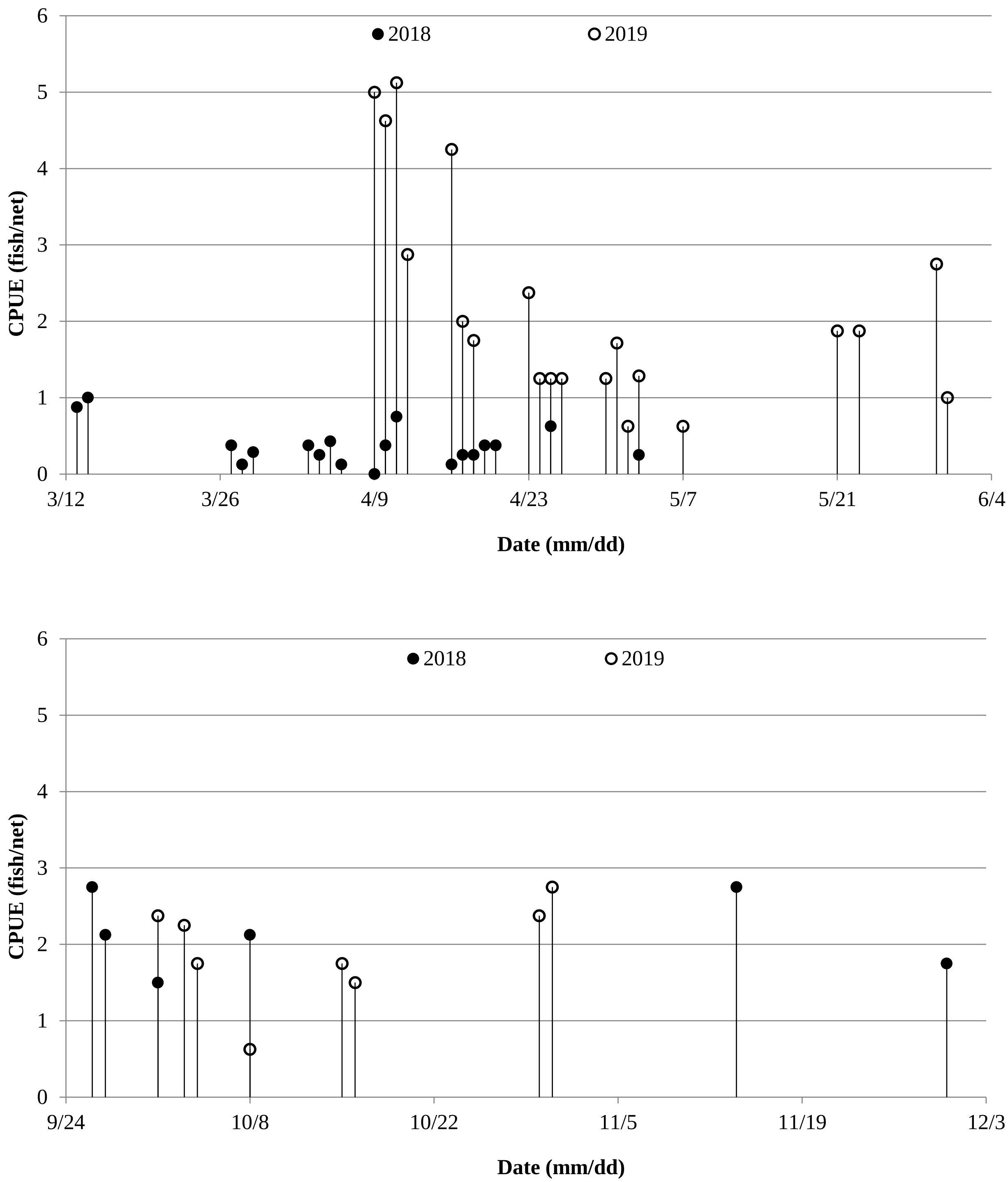


Figure 7. Northern pike daily catch rates (CPUE; fish/net) for overnight gillnet deployments during spring (top panel) and fall (bottom panel) suppression periods in Windy Bay of Coeur d'Alene Lake in 2018 and 2019.

During fall suppression periods in Windy Bay, a total of 48 nets were deployed in 2018 and 104 northern pike were captured. Daily catch rates averaged 2.2 fish/net over six days of deployment that occurred from September 26 to November 30, with no evidence of a declining trend over time (Figure 7). In 2019, a total of 58 nets were deployed in which 109 pike were captured. A declining trend in catch rates was also not apparent in 2019, where eight days of deployment from October 1-31 yielded an average catch of 1.9 fish/net (Figure 7). Suppression was terminated at the end of October because of the elevated catch of mature kokanee.

The size distribution of northern pike captured during the spring in Windy Bay markedly shifted to a smaller class of individuals from 2018 to 2019 (Figure 8). In 2018, fifty percent of pike were at least 750 mm in length, with 22% smaller than 600 mm. In comparison, 88% of fish captured in 2019 were smaller than 600 mm, with few fish captured that were larger than 750 mm. Large pike were also scarce in the catch during both fall suppression periods in that only 9-13% of captured fish were greater than 750 mm. In 2018, fish smaller than 600 mm dominated the catch (71%), but in 2019 a lower percentage was captured across the two smallest size classes and a higher percentage was captured between 600 and 750 mm.

From 2015 to 2018, the number of pike annually removed from Windy Bay during the spring had declined by more than 80% (Figure 9). However, the number captured in 2019 exceeded the number removed in the first year of suppression. Though fall suppression was not conducted until 2018, three days of netting were conducted in October of 2017 to evaluate recolonization potential by pike. Only 15 fish were captured at an average rate of 0.6 fish/net, which was markedly lower than that documented in fall netting efforts in 2018 and 2019 (Figure 9).

In the southern end of Lake Coeur d'Alene, a total of 107 nets were deployed during spring suppression efforts and 720 northern pike were captured. Daily catch rates were highly variable from April 9 to May 23, ranging from 0.3 to 15.8 fish/net, a result not unexpected given that a combination of exploratory sampling and telemetry data were used to evaluate the locations of pike spawning aggregations across the southern end. Highest overall catch rates of pike were found in Benewah Lake (7.6 fish/net) and Round Lake (8.2 fish/net) in the eastern extent of the suppression area, though catch rates declined in each location throughout the spring (Table 1). Benewah and Round lakes also yielded the largest single net catches of pike of 31 and 26 fish, respectively. In comparison, overall spring catch rates of pike in Hidden Lake (4.2 fish/net) and Chatcolet Lake (5.5 fish/net) were lower than the other two eastern locations, though catch rates increased in Chatcolet Lake throughout the spring (Table 1).

Catch rates of various species were found to differ between the variable mesh and large mesh nets that were deployed in the southern end during the spring of 2019 (Table 2). Catch rates of northern pike were 1.8 times greater in the variable than in the large mesh nets. Black crappie were also captured more frequently in the variable than in the large mesh nets, and catch rates of brown bullhead in variable mesh nets approached 15 fish/net whereas they were rarely captured with large mesh nets. Conversely, catch rates for each of four large-bodied species - largescale sucker, tench, northern pikeminnow, and largemouth bass – were approximately twice as great in the large than in the variable mesh nets.

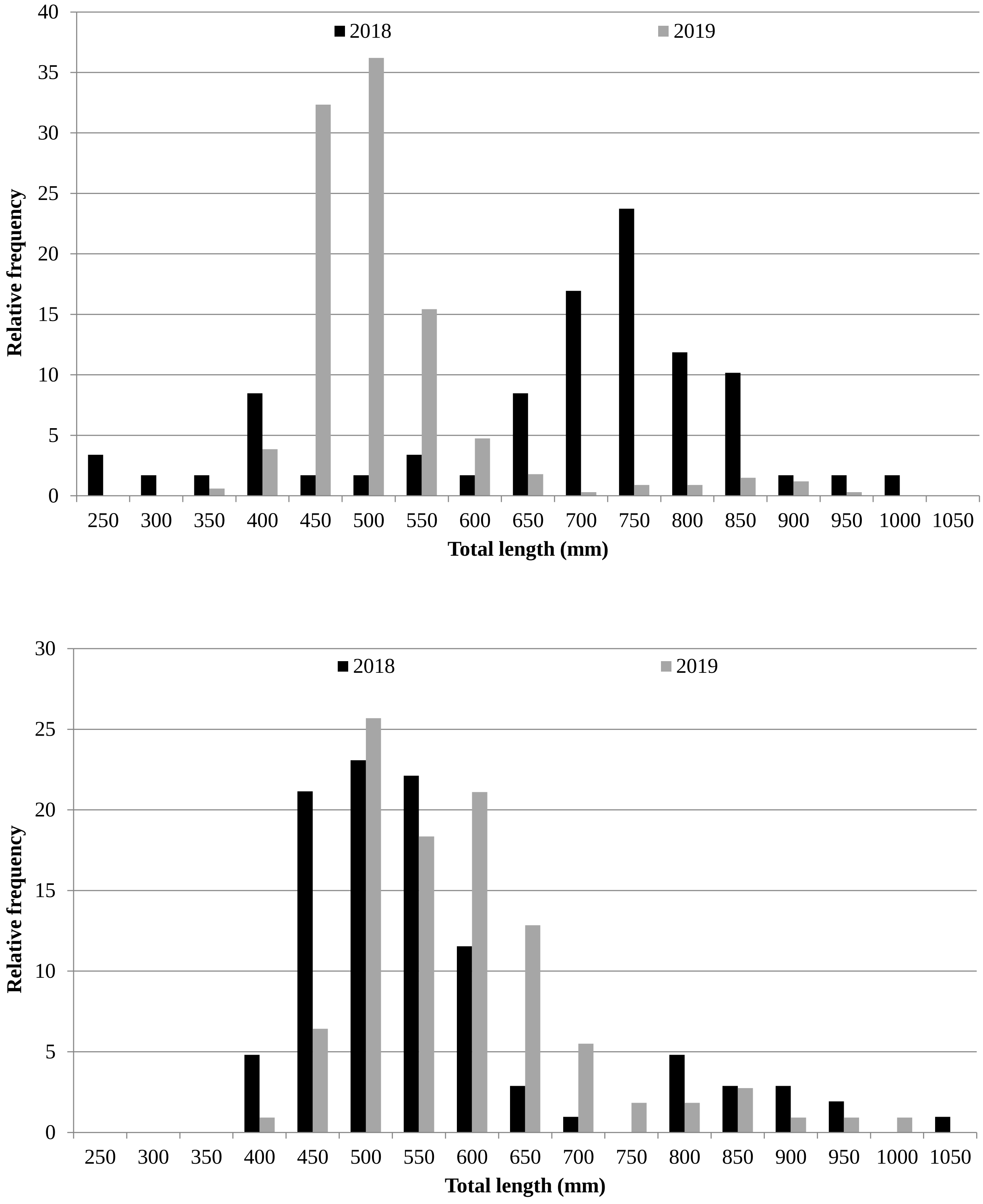


Figure 8. Length distribution of northern pike captured in spring (top panel) and fall (bottom panel) suppression efforts in Windy Bay of Coeur d'Alene Lake in 2018 and 2019.

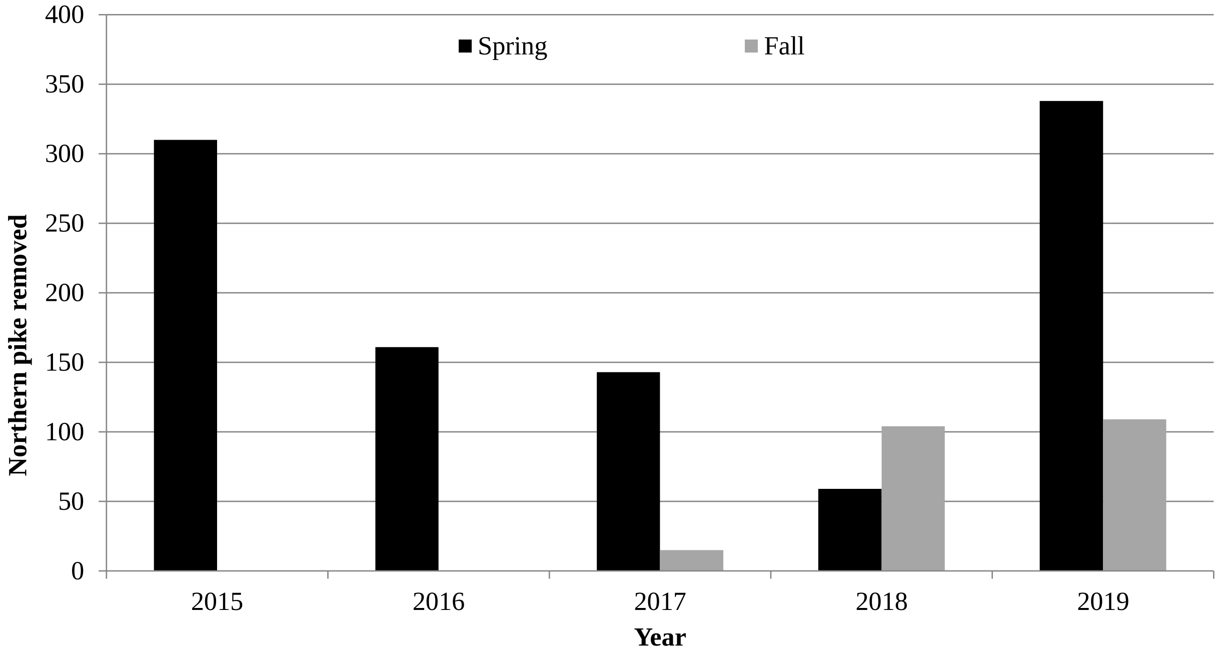


Figure 9. Number of northern pike annually removed from Windy Bay in Coeur d'Alene Lake during spring and fall suppression periods, 2015-2019.

During the fall, a total of 111 nets were deployed across the southern end and 689 northern pike were captured. Five days of systematic netting around the shoreline perimeter occurred from October 2 to November 5 to evaluate areas where pike were concentrated (Figure 10). The largest concentration of pike was found on the western shore of Lake Chatcolet where catch rates across six deployments averaged 7.8 fish/net (range 2-12 fish). A comparable high density of pike was also found in the Benewah Lake area, west of the train trestle, where catch rates across five deployments averaged 6.2 fish/net (range, 4-10 fish). High catches of pike occurred in other areas, but they were generally restricted to a few locations (e.g., west end of Round Lake). From November 6th to the 21st, deployments occurred only in Lake Chatcolet, where 555 pike representing 80% of the fall total were removed over nine days of effort. Catch rates averaged 7.7 fish/net (range, 6.4-10.4) over this time, and did not exhibit a declining trend.

The size of northern pike captured during 2019 suppression efforts in the southern end exhibited a more protracted length distribution than that observed in Windy Bay (Figure 11). For pike removed during the spring, 44% of fish were less than 600 mm in length, while 25% of the fish removed were at least 750 mm in length. The size distribution of pike captured during the fall encompassed size classes comparable to that observed in the spring, though a higher percentage of captured fish were between 600 and 750 mm in length, and only 10% were greater than 750 mm. Large mesh nets, which were only deployed in the spring, captured large size classes of pike at a higher percentage than variable mesh nets (Figure 12).

Table 1. Deployment and northern pike catch metrics for spring suppression efforts in the southern end of Coeur d'Alene Lake in 2019.

	Deployment metrics		Northern pike catch metrics		
Suppression period	Days	Total nets	CPUE (fish/net)	Percent positive nets[a]	Maximum catch
			Benewah Lake		
April 8 - April 25	4	20	8.7	75	31
April 29 - May 9	1	4	7.0	100	8
May 13 - May 23	1	6	4.7	100	13
Total	**6**	**30**	**7.6**	**83**	**31**
			Round Lake		
April 8 - April 25	.	.	.	.	.
April 29 - May 9	2	10	13.1	100	26
May 13 - May 23	3	19	5.6	100	16
Total	**5**	**29**	**8.2**	**100**	**26**
			Chatcolet Lake		
April 8 - April 25	2	12	4.5	92	12
April 29 - May 9	1	6	6.2	100	11
May 13 - May 23	1	8	6.4	100	14
Total	**4**	**26**	**5.5**	**96**	**14**
			Hidden Lake		
April 8 - April 25	.	.	.	.	.
April 29 - May 9	2	8	5.4	88	12
May 13 - May 23	1	6	2.7	67	6
Total	**3**	**14**	**4.2**	**79**	**12**

[a] Number of nets where at least one northern pike was captured

Table 2. Catch rates for select species using large mesh (i.e., 5.1 cm bar mesh) and variable mesh (i.e., three equivalent panels of 3.8, 4.4, and 5.1 cm bar mesh) gillnets during spring suppression efforts in the southern end of Coeur d'Alene Lake in 2019.

		Catch rates (fish/net)								
Mesh size	Nets deployed	Northern pike	Largescale sucker	Tench	Northern pikeminnow	Largemouth bass	Smallmouth bass	Black crappie	Yellow perch	Brown bullhead
Large	48	5.04	5.21	4.31	3.21	3.35	0.46	1.40	0	0.27
Variable	45	8.89	2.76	1.93	1.67	1.91	0.56	5.36	0.47	14.78

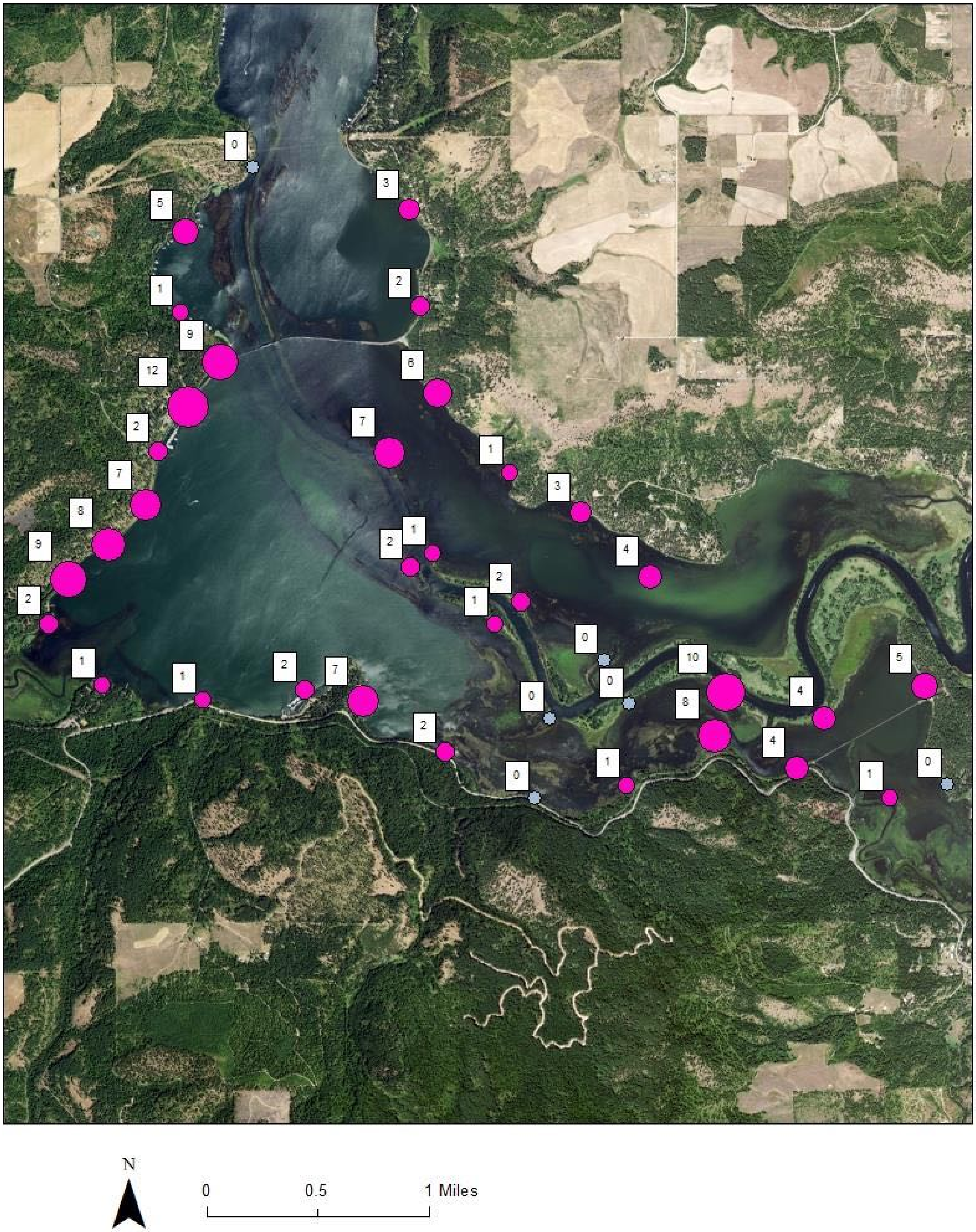


Figure 10. Number of northern pike captured in gillnets deployed at waypoints systematically sampled around the shoreline perimeter of the southern end of Coeur d'Alene Lake in the fall of 2019. Relative size of each circle depicts the number captured which is also displayed alongside the symbol. Locations in which pike were not captured are colored in grey.

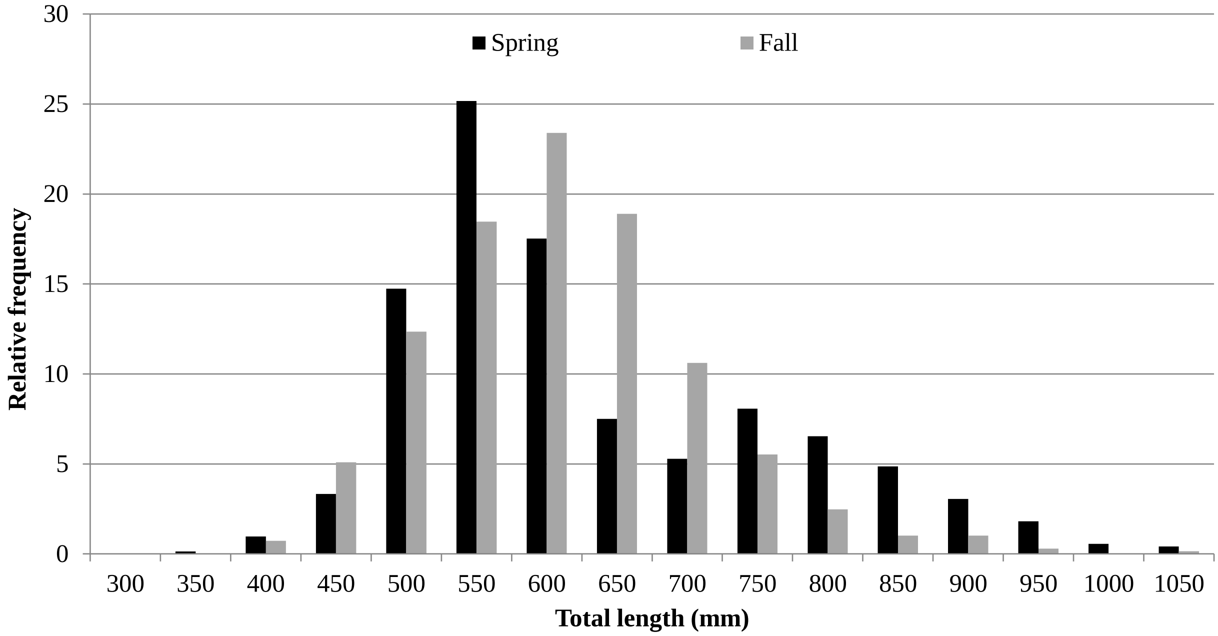


Figure 11. Length distribution of northern pike captured in spring and fall suppression efforts in the southern end of Coeur d'Alene Lake in 2019.

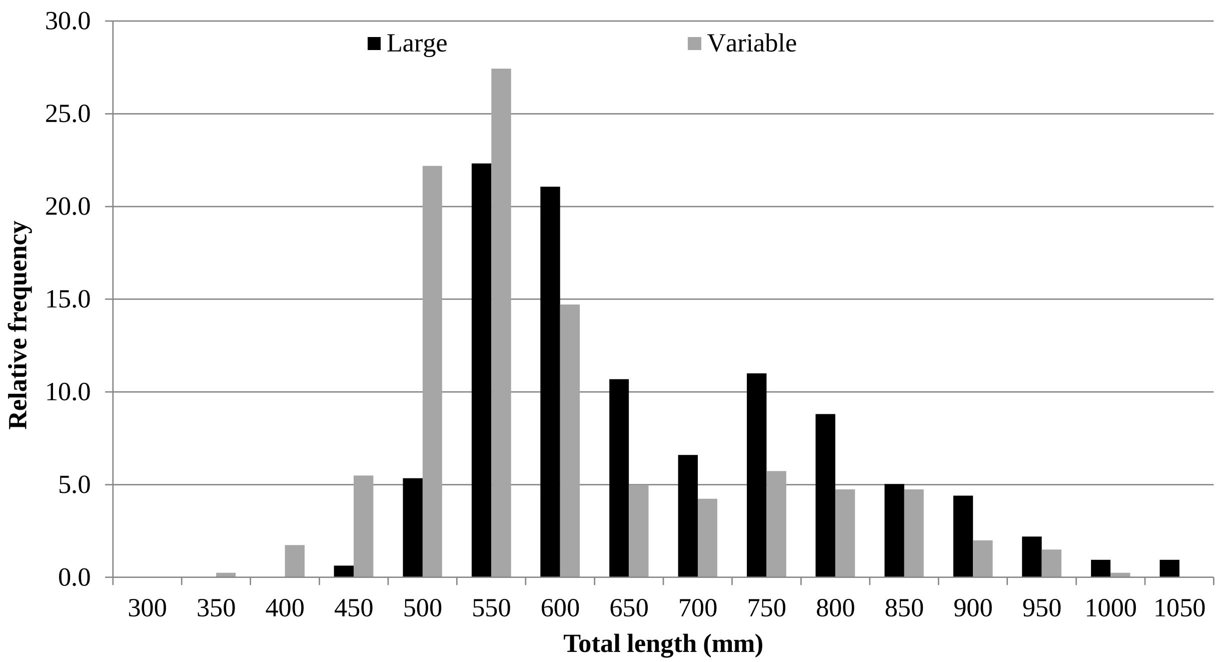


Figure 12. Length distribution of northern pike captured in large mesh and variable mesh nets during spring suppression efforts in the southern end of Coeur d'Alene Lake in 2019.

Though northern pike was the most dominant species captured collectively over spring and fall suppression efforts in Windy Bay and the southern end of the lake in 2019, differences in catch composition for other species were observed between seasonal periods and across locations (Table 3). In Windy Bay, smallmouth bass and kokanee comprised a substantially higher percentage of the catch in the fall (23 and 15%, respectively) than in the spring (6 and 0%, respectively), whereas brown bullhead, which comprised 29% of the spring catch, constituted only 8% of fish captured in the fall. In the southern end, compositional differences between seasonal periods were not as pronounced as those observed in Windy Bay, though largemouth bass and black crappie, two prevalent sport fishes, comprised a greater percentage of the catch in the spring (10 and 11%, respectively) than in the fall (5 and 6%, respectively). Conversely, largescale suckers comprised only 14% of the catch in the spring, whereas they constituted 24% of the fish captured in the fall. Generally, relative to the number of nets deployed, numbers of fish captured for many of the prevalent species in the southern end were greater in the spring than in the fall, and collectively over both suppression periods most species were substantially more abundant in the catch in the southern end than in Windy Bay (Table 3). However, smallmouth bass, cutthroat trout, and kokanee were more frequently captured in Windy Bay than in the southern end of the lake.

Mortality rates for many of the captured species were generally low across both locations during suppression efforts in 2019, though in some instances rates were relatively high exceeding 15% (Table 3). For example, mortality rates of northern pikeminnow ranged between 19-24% in the spring for both locations, though in the fall they were markedly lower. Mortality rates for largemouth bass were also high in the spring in both locations and in the fall in the southern end (17-19%), though the number of bass that perished in the southern end was lower in the fall than in the spring. Similarly, though the fall mortality rate for smallmouth bass in the southern end was 30%, this level accounted for only 3 fish. Salmonids that were captured over suppression efforts consistently perished at the greatest rates of all species, though few salmonids were captured in both locations in 2019.

Twenty-five northern pike, ranging from 580 to 910 mm in total length, were implanted with radio-tags in the southern end of the lake in the fall of 2018. Eighteen and seven of these fish were captured and released in Chatcolet Lake and Benewah Lake, respectively. During wintertime tracking events from December of 2018 through March of 2019, nineteen fish were located in Chatcolet Lake, four of which had been tagged in Benewah Lake (Figure 13). Two of the fish tagged in Chatcolet Lake were found in Hidden Lake, and three fish remained in Benewah Lake. Tagged fish were not found to move among the three general areas throughout winter tracking events.

In the spring after ice receded from the lake, many of the radio-tagged northern pike were found to promptly move eastward (Figure 14). Of the twelve fish that overwintered in Chatcolet Lake that were successfully tracked in the spring, two were located in the eastern extent of Round Lake, four moved into Benewah Lake, and five migrated up the St. Joe River with four of these fish located in Hepton Lake (St. Joe rkm 15) and the other located in a backwater slough 48 kilometers upriver. Two of the three fish that overwintered in Benewah Lake remained there in the spring; the other one migrated upriver to access Hepton Lake. The two fish that overwintered in Hidden Lake were also located there throughout the spring. Incidentally, five of the six fish that were found up the St. Joe River in the spring subsequently returned to the southern end of the lake where they were either harvested, captured in gillnets, or located by radio telemetry; the other fish was not located despite several tracking events throughout the summer and fall that were conducted by boat down the St. Joe River. Overall, fourteen of the twenty-five tagged fish (56%) have either been reported harvested by anglers or captured during suppression efforts in 2019.

Table 3. Species composition and mortality rates for fish captured in spring and fall suppression efforts in Windy Bay and the southern end of Coeur d'Alene Lake in 2019.

	Windy Bay				Southern end of Coeur d'Alene Lake			
	Species Composition		Species mortality		Species Composition		Species mortality	
Species	Number Captured	Percent of total	Number dead	Percent of total	Number Captured	Percent of total	Number dead	Percent of total
				Spring				
Northern pike	338	25.61	.	.	720	22.46	.	.
Catostomus spp.	139	10.53	3	2	446	13.92	19	4
Tench	117	8.86	0	0	321	10.02	0	0
Northern pikeminnow	90	6.82	17	19	257	8.02	61	24
Largemouth bass	57	4.32	11	19	321	10.02	55	17
Smallmouth bass	85	6.44	1	1	47	1.47	1	2
Black crappie	61	4.62	0	0	364	11.36	20	5
Yellow perch	12	0.91	0	0	21	0.66	1	5
Lepomis spp.	2	0.15	0	0	20	0.62	1	5
Brown bullhead	388	29.39	0	0	682	21.28	0	0
Cutthroat trout	28	2.12	7	25	0	0	.	.
Kokanee	0	0	.	.	0	0	.	.
Rainbow trout	3	0.23	3	100	1	0.03	1	100
Brook trout	0	0	.	.	1	0.03	0	0
Bull trout	0	0	.	.	4	0.12	3	75
				Fall				
Northern pike	109	17.52	.	.	689	30.09	.	.
Catostomus spp.	44	7.07	3	7	549	23.97	8	1
Tench	90	14.47	1	1	94	4.10	0	0
Northern pikeminnow	9	1.45	1	11	49	2.14	2	4
Largemouth bass	19	3.05	2	11	104	4.54	18	17
Smallmouth bass	146	23.47	15	10	10	0.44	3	30
Black crappie	26	4.18	1	4	126	5.50	3	2
Yellow perch	13	2.09	1	8	49	2.14	3	6
Lepomis spp.	5	0.80	0	0	24	1.05	2	8
Brown bullhead	49	7.88	0	0	581	25.37	0	0
Cutthroat trout	20	3.22	4	20	8	0.35	3	38
Kokanee	92	14.79	23	25	7	0.31	3	43
Rainbow trout	0	0	.	.	0	0	.	.
Brook trout	0	0	.	.	0	0	.	.
Bull trout	0	0	.	.	0	0	.	.

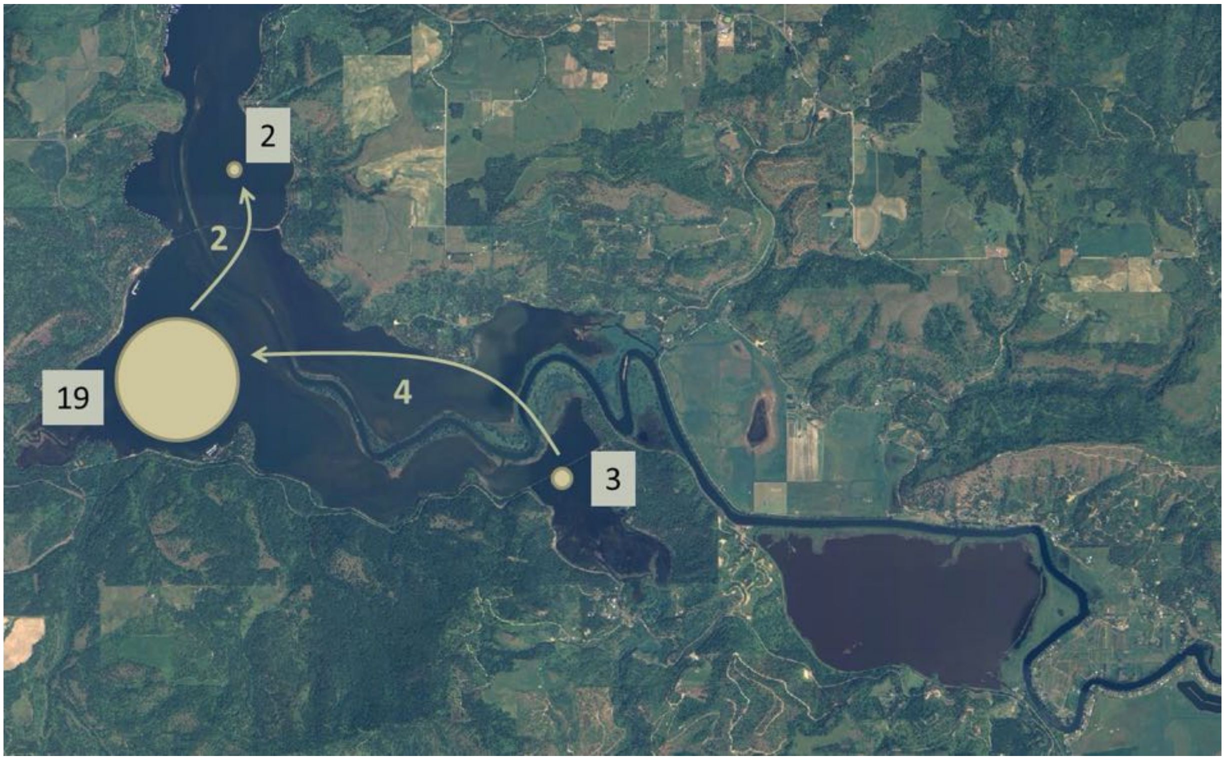


Figure 13. Distribution of radio-tagged northern pike in the southern end of Coeur d'Alene Lake from December 2018 to March 2019. Relative size of circles depicts number detected, which is also illustrated, and numbers alongside arrows indicate movements from fall tagging locations.

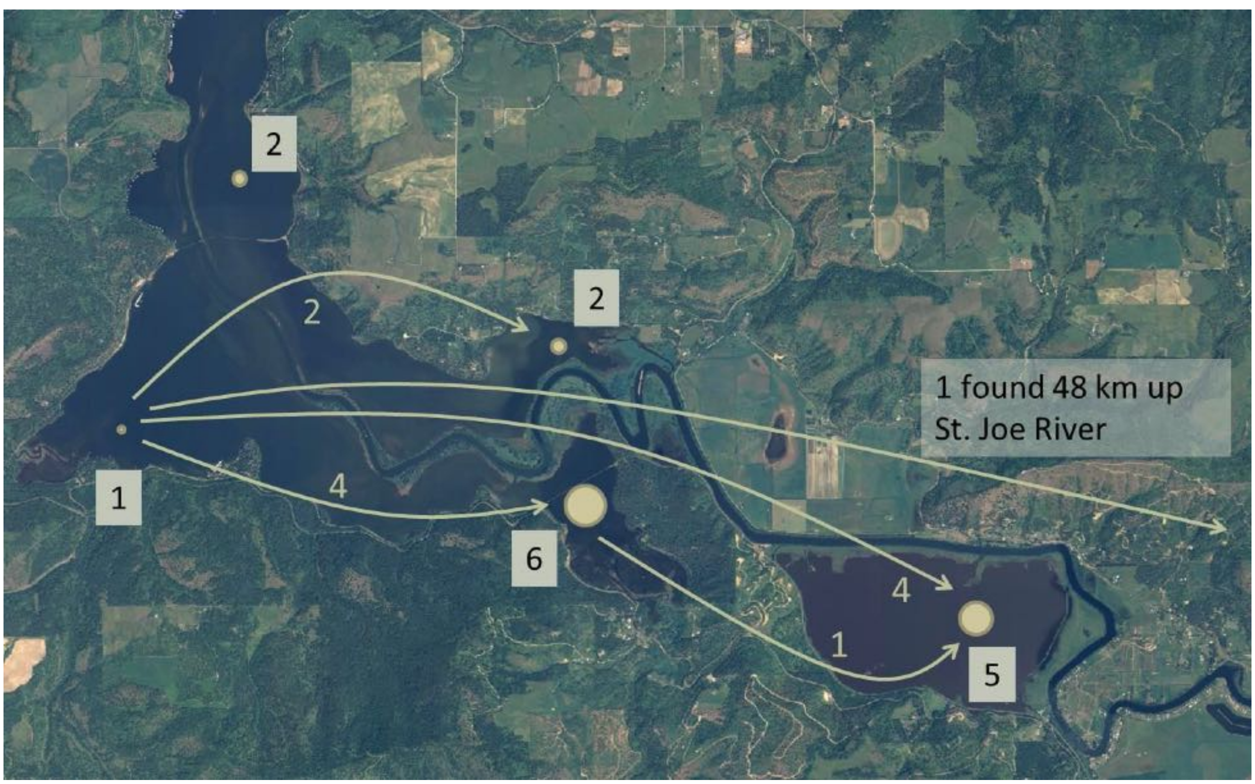


Figure 14. Distribution of radio-tagged northern pike in the southern end of Coeur d'Alene Lake during spring periods in 2019. Relative size of circles depicts number detected, which is also illustrated, and numbers alongside arrows indicate movements from overwintering locations.

3.2 Status and trend of westslope cutthroat trout populations

3.2.1 Abundance and productivity of adfluvial cutthroat trout at the watershed scale

Lake Creek

In Lake Creek, 127 ascending and 196 descending adfluvial adult WCT were captured in the migrant trap in 2018. Excluding recaptures, 65 (30%) of the adults were males (mean TL, 371 mm) and 148 were females (mean TL, 348 mm). In 2019, 168 ascending and 325 descending adfluvial adult WCT were captured in the migrant trap. Excluding recaptures, 94 (25%) of the adults were males (mean TL, 378 mm) and 278 were females (mean TL, 355 mm). Spawner abundance estimates of 235±12 and 492±96 were generated from recaptured marked fish in 2018 and 2019, respectively.

A total of 1617 outmigrating juvenile WCT was captured in Lake Creek in 2018 of which 519 received PIT tags. Eighteen trap efficiency trials were conducted from April 3 to June 4 (mean, 27 fish/trial) to generate an outmigrant abundance estimate of 4365±728 fish. Trap efficiencies averaged 40% over the release trial periods, with only one trial efficiency estimated at less than 20% (Table B-2). In 2019, a total of 1659 outmigrating juvenile WCT was captured of which 669 received PIT tags. Release trials were not conducted in 2019 so an outmigrant abundance estimate was not generated.

In the spring of 2019, twenty-two juveniles that were tagged the preceding summer across a 2 km reach in the UFL sub-drainage (rkm 16.6-18.6) were interrogated outmigrating past the HDX antenna at rkm 7.8. Approximately 60% of these fish left during an 11 d period from May 10 to May 21 (Figure 15). Coincident with this pulse was an observed increase in the condition of all juveniles captured in the outmigrant trap. Mean condition factor increased from 0.88 prior to May 15 to a value of 0.94 computed over a 14 d period from May 16 to May 30 (Figure 15). Growth rates of fish tagged in the UFL sub-drainage that were recaptured in spring also increased over the outmigration period, with mean growth rates doubling from late April to June (Figure 15). Incidentally, the three fish captured during the early portion of the outmigration averaged 153 mm at time of capture and averaged 130 mm when tagged the preceding summer; the five fish recaptured in June similarly averaged 155 mm at capture though they were tagged at a mean size of only 99 mm.

Benewah Creek

In Benewah Creek, eight ascending and seven descending adfluvial adult WCT were captured in the migrant trap in 2018. Excluding recaptures, five (38%) of the adults were males (mean TL, 389 mm) and eight were females (mean TL, 345 mm). A spawner abundance estimate of 23±15 was generated from recaptured marked fish. A total of 281 outmigrating juvenile WCT was captured in Benewah Creek in 2018 of which 189 received PIT tags. Thirteen trap efficiency trials were conducted from March 26 to May 21 (mean, 15 fish/trial) to generate an outmigrant abundance estimate of 651±133 fish. Trap efficiencies averaged 45% over the release trial periods, with only one trial efficiency estimated at less than 20% (Table B-2). Migrant traps were not deployed in 2019 so adult and juvenile outmigrant estimates were not generated.

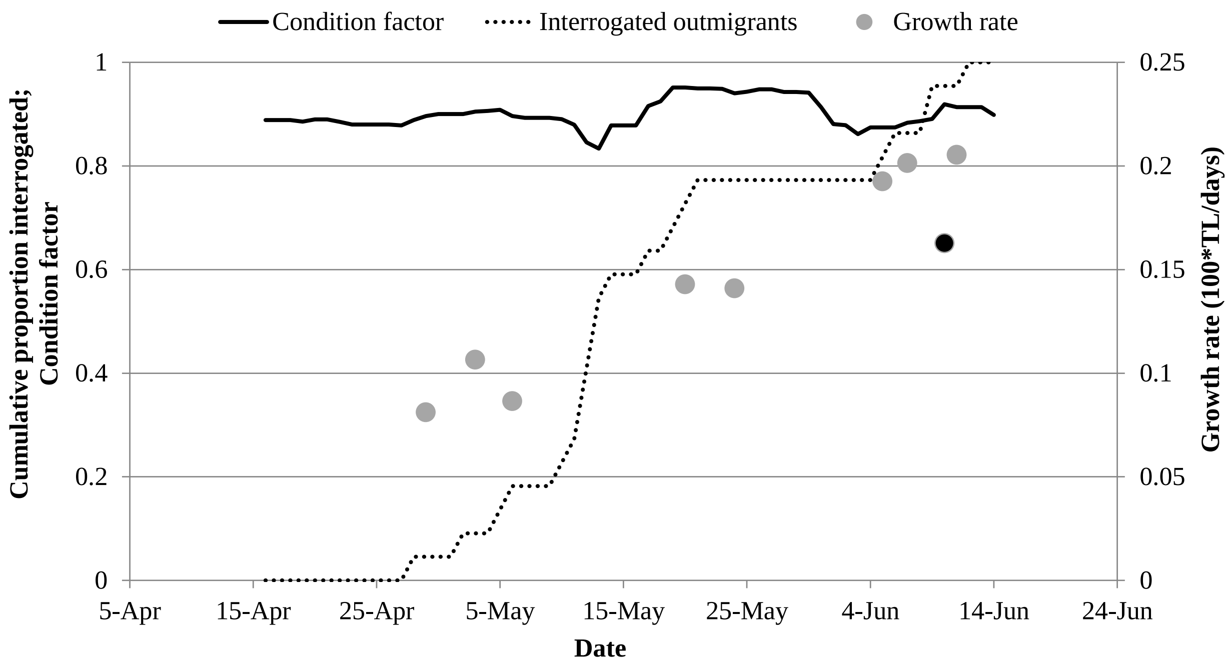
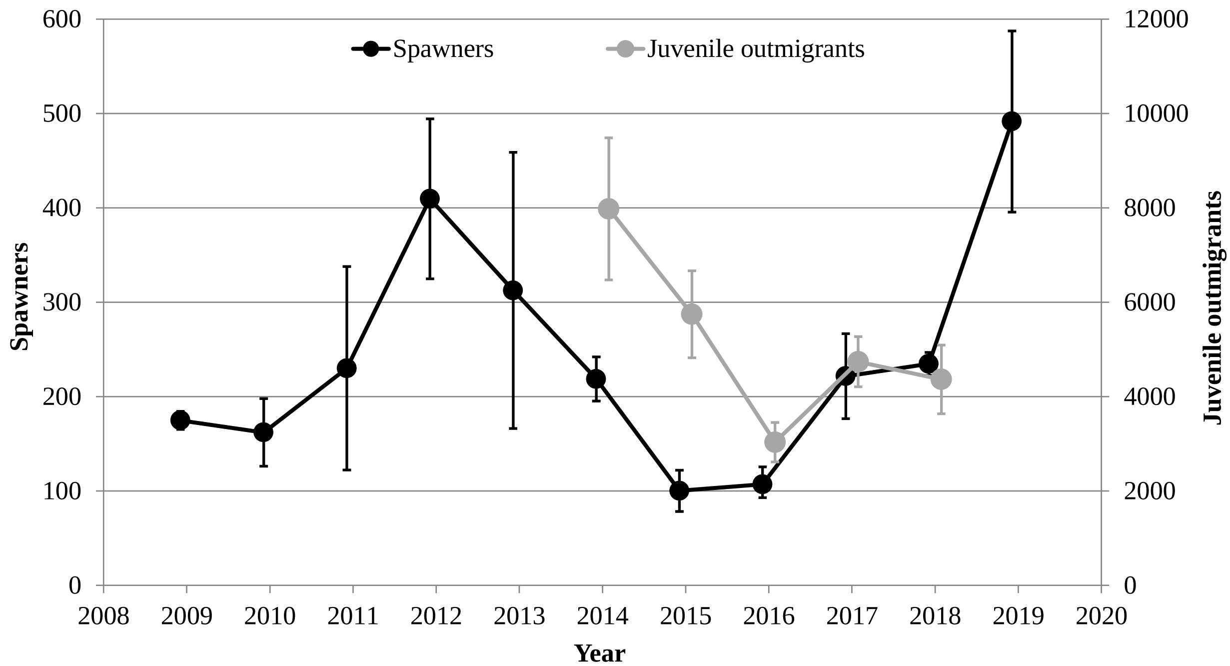


Figure 15. Seven day running averages of condition factor, and growth rates of fish PIT-tagged the preceding summer in the UFL sub-drainage (darkened circle represents two fish) for juvenile WCT that were captured in outmigrant traps in Lake Creek in 2019. The timing of fish PIT-tagged in the UFL sub-drainage that were interrogated at rkm 7.8 in the spring of 2019 is also illustrated.

Temporal trends of adfluvial cutthroat trout

Annual estimates of adfluvial spawners have varied by approximately five-fold over the last eleven years in Lake Creek (Figure 16). Over 400 spawners were estimated to have ascended in 2012, but estimates before that time averaged just under 200 fish. From 2012 to 2016, abundance estimates had markedly declined to low levels of 100 fish. Since 2016, however, abundance estimates have increased considerably with a doubling of spawners from 2018 to 2019. Furthermore, the 2019 estimate of 492 fish was the largest recorded over the monitoring period. In Benewah Creek, spawner abundance estimates have consistently been lower than those in Lake Creek, and an overall decline in numbers has been observed with an average of approximately 22 fish since 2013 (Figure 16).

Juvenile outmigrant abundance estimates in Lake Creek have ranged from a low of 3000 to a high of 8000 and have mostly tracked spawner abundance estimates two years prior (Figure 16). In Benewah Creek, the number of juvenile outmigrants peaked at 2300 fish in 2014 but has declined to low levels ranging between 650 and 920 from 2016 to 2018, a trend comparable to that observed in adult returns (Figure 16). Outmigrant estimates prior to 2014 in Lake Creek and prior to 2013 in Benewah Creek, which were obtained using a fixed-panel trap, were negatively biased because of the trap's inability to effectively operate under moderate to high flows and consequently were not illustrated.



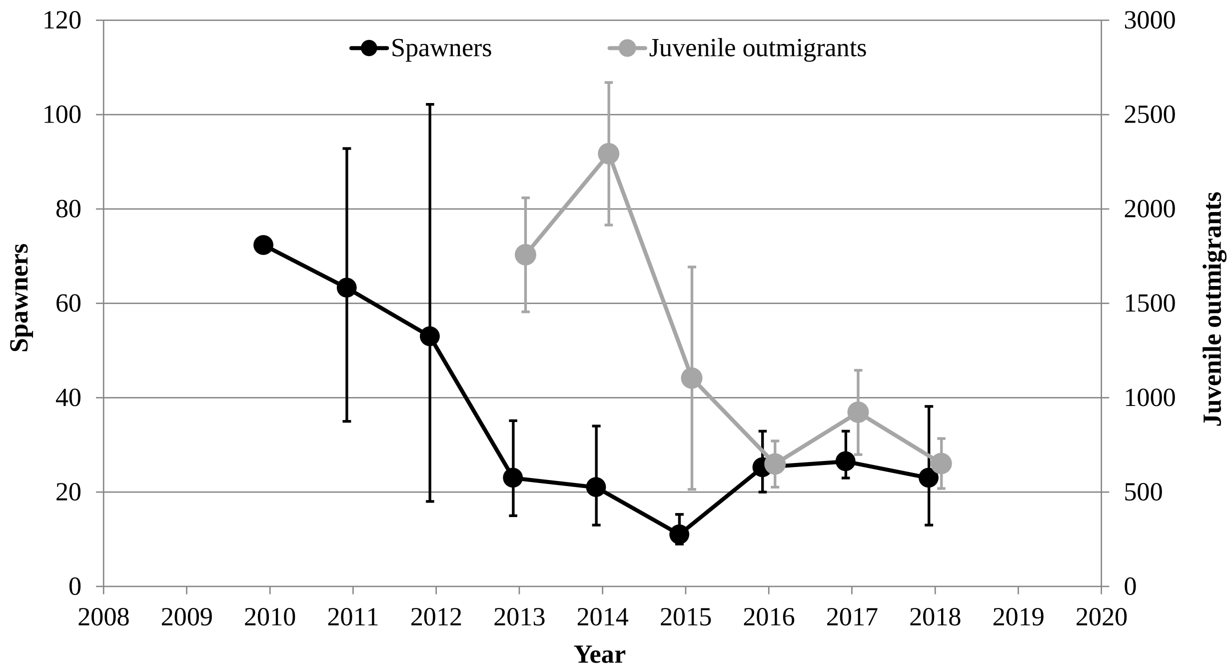


Figure 16. Abundance estimates with 95% confidence intervals for WCT adfluvial spawners and juvenile outmigrants in Lake Creek (upper panel) and Benewah Creek (lower panel) from 2009 to 2019. Note the different scales for both life stages between watersheds.

In the Lake Creek watershed, the percentage of WCT tagged as adults and juvenile outmigrants that have been found to return in subsequent years to spawn has increased since 2015 (Figure 17). Adults tagged from 2015 to 2018 have returned as repeat spawners at rates averaging 47%, though the repeat spawn rate of the 2017 tagged class was only 30%. In comparison, repeat spawn rates averaged 32% prior to 2015 and had exhibited a declining trend. Juveniles tagged in 2015, 2016, and 2017 were found to return to spawn within two years of tagging at rates of 2.4, 4.1, and 4.6%, respectively. In comparison, two-year return rates for prior outmigrant cohorts averaged 1%. In addition, another 2% of fish from those tagged in 2016 returned in 2019, increasing the overall return rate for this cohort to 6.1%, a four-fold increase over the overall return rate averaged for cohorts tagged from 2005 to 2014. Generally, larger outmigrants tagged from 2015 to 2017 returned at greater rates than smaller fish (Figure 18). For example, though approximately 40% of juveniles tagged over this period were less than or equal to 150 mm, only 7% of this size class has been found to return. However, juveniles from 2015 to 2017 that were tagged at sizes between 150 and 200 mm have returned at markedly higher rates than those tagged in this size range prior to 2015 (Figure 19). In the Benewah Creek watershed, return rates of juvenile outmigrants have averaged 0.6% from 2007 to 2017; only two fish from cohorts tagged since 2011 have been found to return (Figure 17).

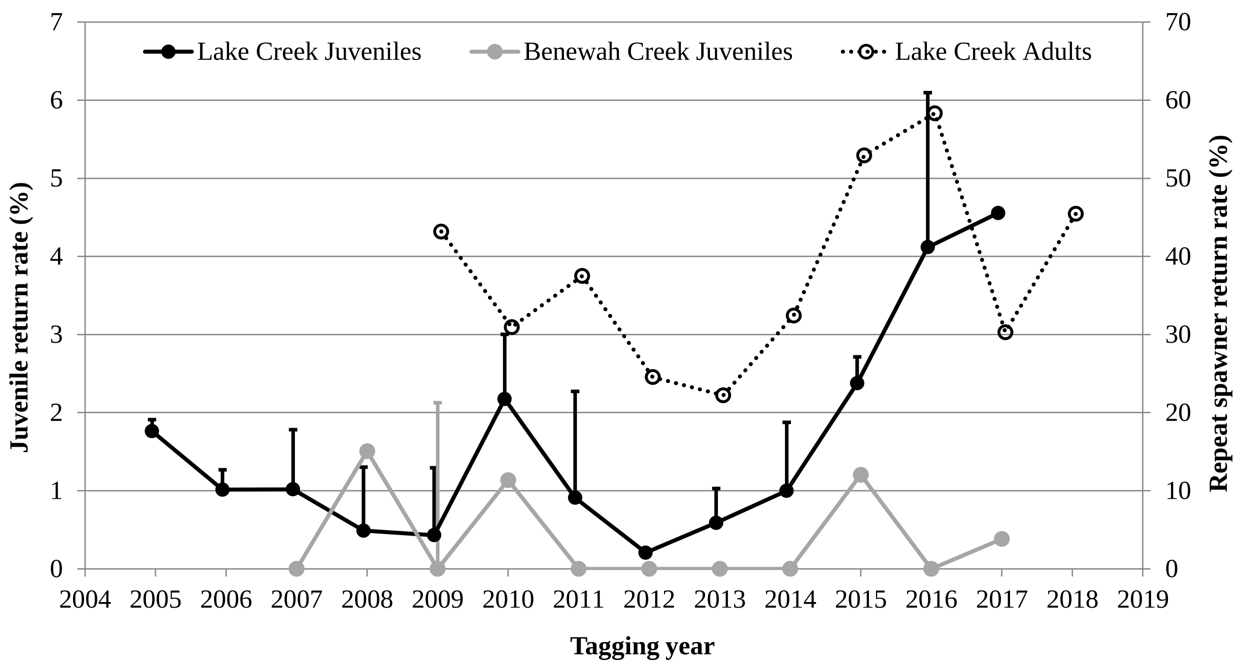


Figure 17. Return rates of WCT tagged as ascending adults in Lake Creek and as outmigrating juveniles in both Lake and Benewah creeks during spring migratory periods, 2005-2018. For tagged juveniles, the circles represent the percentage of fish returning within two years of tagging, and the vertical bars represent the additional percentage of fish that required more than two years to return.

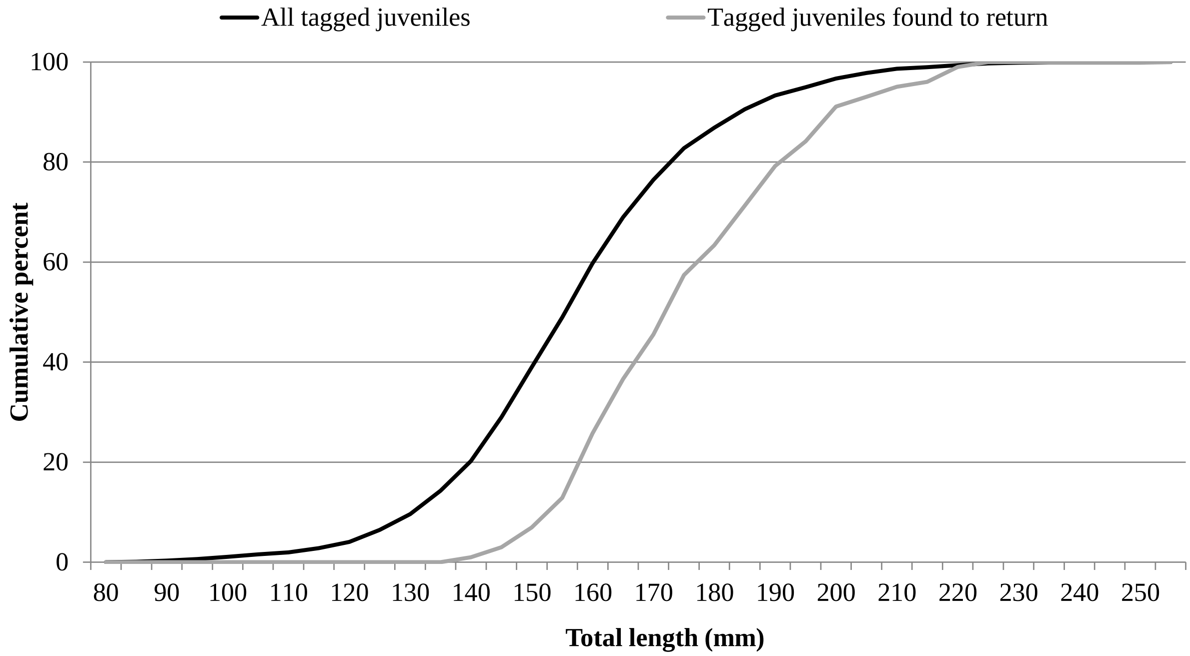


Figure 18. The size distribution of juvenile WCT outmigrants that were tagged from 2015 to 2017, and the size distribution of tagged fish from these cohorts that were found to return as adfluvial adults.

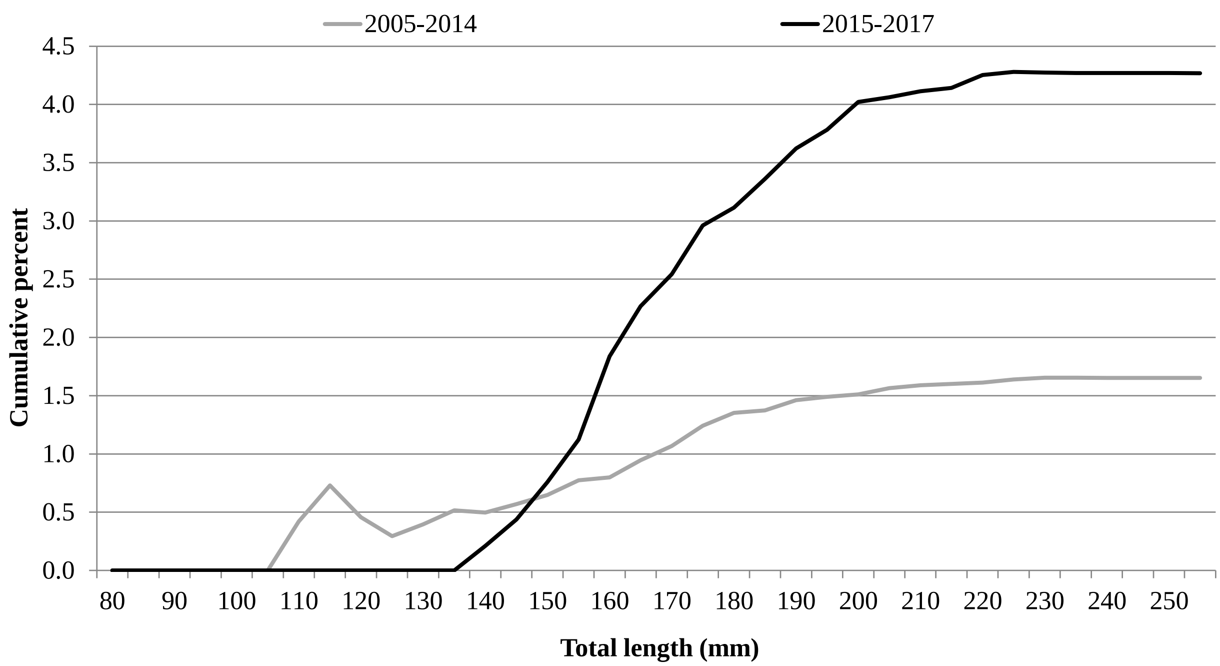


Figure 19. The percentage of juvenile WCT tagged across size classes that have been found to return as adfluvial adults for cohorts outmigrating from 2005 to 2014 and from 2015 to 2017 in the Lake Creek watershed.

3.2.2 Abundance and life-history diversity of cutthroat trout at sub-drainage scales

Benewah Creek watershed

Twenty-nine sites across four sub-drainages in the upper Benewah watershed were surveyed in 2018 to generate density indices (fish/100 m) for age 1+ WCT. Overall mean densities ranged between 17.8 and 20.4 for the SFB, WFB, and Schoolhouse sub-drainages in 2018 (Figure 20). For these sub-drainages, which all exhibited a substantial decline in overall density from 2015 to 2016, the 2018 densities were respectively greater than those generated in 2016. Relative to density values generated from 2013 to 2015, 2018 densities were within 79-82% of their peak values in the SFB and Schoolhouse sub-drainages, and at 69% of the peak value in the WFB sub-drainage. In comparison, the mean density index generated in the Windfall sub-drainage in 2018 was considerably lower than those generated for the other sub-drainages and averaged only 11.3 fish/100 m (Figure 20). Windfall exhibited the most significant decline from 2015 to 2016 of all sub-drainages, averaging only 5.1 fish/100 m in 2016, and the 2018 density value was only 46% of the peak value generated for this sub-drainage from 2013 to 2015.

Lake Creek watershed

Six sites distributed across a 2 km reach in the UFL sub-drainage (rkm 16.6-18.6) in the Lake Creek watershed were surveyed in the summer of 2018 to generate density indices for age 1+ WCT. The overall mean density calculated across this reach was 39.9 fish/100 m, with values ranging between 23.3 and 58.0. In the summer of 2019, only the upstream-most five sites were surveyed to generate an overall mean density of 56.6 fish/100 m, with values ranging between 39.6 and 81.7. Densities at all sites were greater in 2019 than their respective values in 2018. A total of 154 and 141 fish was respectively PIT tagged across these sites in 2018 and 2019 to evaluate outmigration rates from this reach.

In 2019, twenty-six fish tagged in 2018 were interrogated moving downriver during spring outmigration periods, with site-specific outmigration rates ranging between 3 and 31% (mean, 19%). The mean adfluvial index generated from these six sites was 6.5 (range, 1.7-10.5). In comparison, mean adfluvial indices generated from 2013 to 2016 across a 2 km reach in the Bozard sub-drainage, where the adfluvial variant was found to be prevalent, were significantly greater than that calculated in the UFL sub-drainage, with annual mean values ranging between 11.7 and 22.4 (Figure 21). Mean adfluvial indices calculated across a 2 km reach in the WFL sub-drainage, where an adfluvial signature was common, were greater in 2013 and 2014 (10.9-13.7) but comparable in 2015 and 2016 (4.3-6.9) to the UFL sub-drainage value (Figure 21).

In 2018 and 2019, approximately two-thirds of PIT-tagged adfluvial adults ascended the Bozard sub-drainage in each year during spring spawning migrations (Table 4). In comparison, only 13% and 9% of ascending adults on average selected the WFL and UFL sub-drainages, respectively. Across both years, an average of 13% of adults was not found to ascend any of the sub-drainages. A high degree of fidelity was observed in repeat spawners in both years. For those adults that were detected selecting a sub-drainage in a prior year, only 3% (i.e., 4 of 117) of the time were they found to ascend a different sub-drainage than that chosen during the reporting period (Table 4). Consistent behavior in past migrations was also observed for those adults that were not interrogated at any of the sub-drainage arrays. Strong fidelity to juvenile rearing habitat was also observed in that eleven fish tagged in the Bozard sub-drainage and four fish tagged in the WFL sub-drainage were all detected ascending their respective tagging sub-drainage over the reporting period.

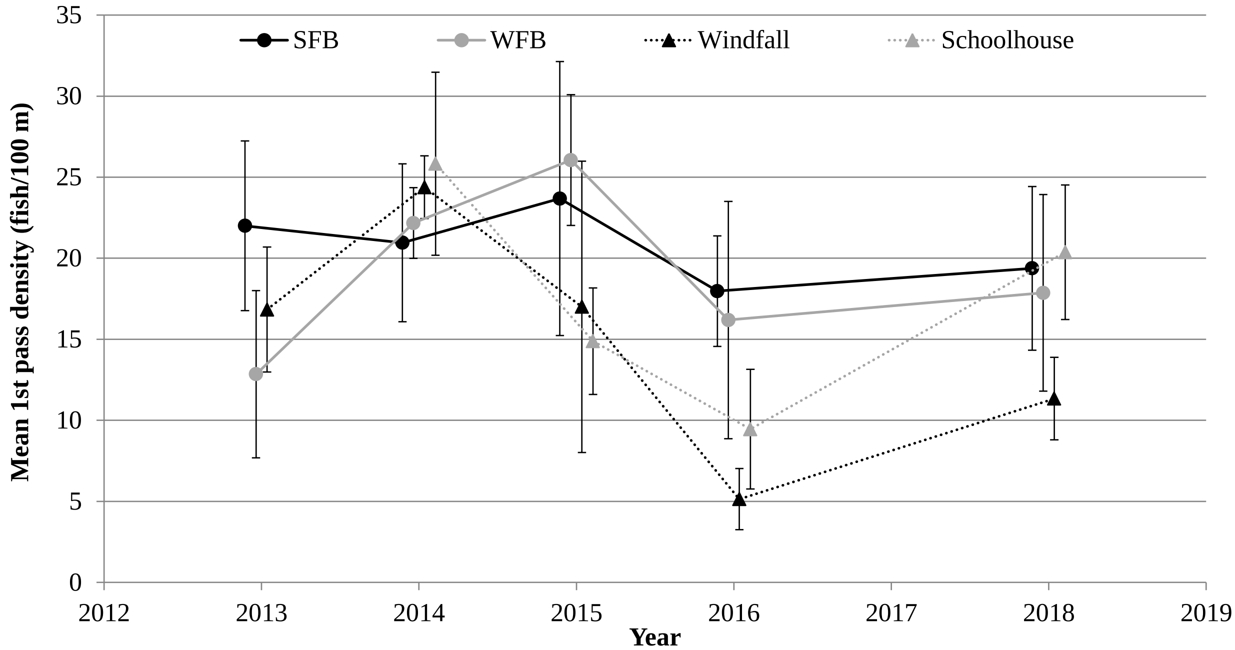


Figure 20. Mean first pass density indices of age 1+ WCT (± one std. error) estimated across index reaches in the SFB, WFB, Windfall, and Schoolhouse sub-drainages in the upper Benewah watershed from 2013 to 2018.

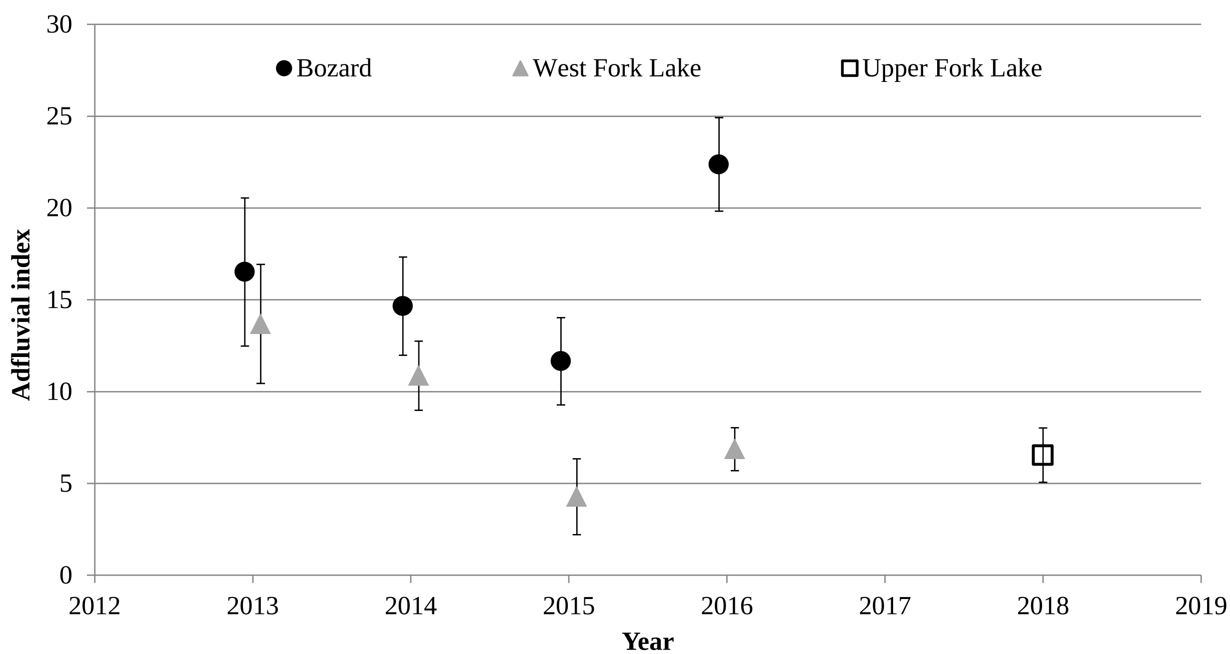


Figure 21. Mean adfluvial indices (± one std. error) estimated across core reaches of sub-drainages in the upper Lake Creek watershed, 2013-2018.

Table 4. Sub-drainages selected by adult adfluvial WCT during spawning migrations in the Lake Creek watershed, 2018-2019. Fish detected at multiple sub-drainage arrays but without an apparent ascension were deemed inconclusive, and some adults were not interrogated at any sub-drainage array. The number of ascensions in prior years by repeat spawners and their fate are also displayed.

	Number (%) selecting sub-drainage		Number (%) of prior ascensions in which same sub-drainage selected over others	
Sub-drainage selected	2018	2019	2018	2019
Bozard	99 (64)	158 (63)	30 (100)	65 (98)
West Fork Lake	23 (15)	29 (12)	1 (50)	7 (88)
Upper Fork Lake	12 (8)	27 (11)	2 (100)	8 (89)
Not interrogated	19 (12)	33 (13)	6 (86) [a]	9 (90) [a]
Inconclusive	2 (1)	5 (2)	.	.

[a] Prior ascensions where fish were not interrogated on sub-drainage antennas

4.0 DISCUSSION

4.1 Effectiveness monitoring of non-native fish suppression

Effectiveness of brook trout suppression efforts

The brook trout suppression program in the upper Benewah watershed has been successful at regulating numbers of brook trout at a depressed, manageable level. During the reporting period, indices of brook trout abundance in mainstem reaches and in reaches of sub-drainages in the upper watershed have virtually been the lowest recorded since inception of the program in 2004. Over a longer effectiveness monitoring time-scale, age 1+ brook trout in both mainstem and sub-drainage reaches have essentially been kept on average at densities less than 3 fish/100 m since 2011, a value significantly less than when the suppression program began. Furthermore, exploratory sampling in 2019 conducted across a 400 m length of mainstem habitat downstream of the 2 km index reach, generated an age 1+ density of only 2.75 fish/100 m. Evidently, brook trout have also been kept in check in other mainstem reaches that have not been addressed by the localized suppression efforts.

It is equally noteworthy that the results documented since 2011 have occurred under levels of annual effort that typically have ranged from 2-4 days compared with the earlier years of the suppression program in which 3 to 4 weeks were invested in removing fish. Initially, the suppression program targeted approximately eight km of mainstem channel length upstream of 9-mile bridge, and lower reaches of sub-drainages in the upper watershed where fish were found to be prevalent. However, much of the mainstem habitat downstream of 12-mile bridge, though serving as suitable rearing habitats (Chisholm et al. 1987; Cunjak 1996; Lindstrom and Hubert 2004; Benjamin et al 2007), likely does not provide suitable spawning habitat because of its depositional nature. Since 2009, tactics have focused on inhibiting reproduction rather than attempting to remove as many fish as possible, and efforts have been curtailed to focus on mainstream reaches upstream of 12-mile bridge that seemingly provide more suitable spawning habitat for brook trout than reaches downriver. Temporary barriers have also been erected upstream of the 12-mile bridge and at the mouth of Windfall Creek as additional measures to inhibit ascending mature brook trout from accessing upstream spawning reaches.

Periodically, however, age 1+ brook trout have been found at elevated levels of abundance in sub-drainage reaches of the upper watershed (e.g., 2014), which has often been associated with an upsurge in the number of age-0 fish found in the focal mainstem reach the prior year. Apparently, this reach of the Benewah mainstem serves as a primary center of spawning activity and a source of individuals for the colonization and establishment of local sub-populations in proximate sub-drainages, a phenomenon that has been documented elsewhere (Benjamin et al. 2007). Further, these results allude to the compensatory resilience that has been documented in brook trout populations (Meyer et al. 2006), and caution against overly relaxing suppression measures. Consequently, suppression tactics should continue to be focused on this mainstem reach annually to check production. In addition, if colonization of sub-drainages has been documented, a small amount of effort may have to be dedicated periodically to lower reaches of these sub-drainages to curb population expansion. In conjunction with the projected negative impacts to brook trout incubation habitat induced by warmer, rainier winters (Wenger et al. 2011), the combination of tactics that are currently being employed should be highly effective under future climate change scenarios at keeping brook trout production down in the upper Benewah watershed.

Coincident with the decline in brook trout, stream surveys have indicated that WCT currently comprise over 80% of the salmonid catch in downstream reaches of primary sub-drainages in the upper Benewah watershed, which is a substantial improvement over that observed when suppression efforts started. In addition, the number of WCT captured across the uppermost 450 m of mainstem habitat addressed during suppression efforts in 2018 and 2019, indicate that WCT also comprised 82-90 % of the salmonid catch in upper mainstem reaches in those years. Incidentally, the increase in the percentage of salmonid composition that comprise WCT has occurred during a time when metrics of WCT adfluvial production in Benewah Creek have declined. It is expected that recovery measures that increase survival rates of migratory life stages of WCT (e.g., northern pike suppression) should further elevate their dominance of the salmonid assemblage in stream rearing habitats in the upper Benewah watershed.

Given the success of suppression tactics implemented in the Benewah watershed, similar measures should be employed in lower reaches of the Evans Creek watershed to control the level of brook trout production that has been observed during the reporting period. Incidentally, prior to 2012, nary a brook trout had been captured in annual stream surveys that had been conducted throughout the watershed since the mid 1990’s. Though the reasons for the sudden proliferation of brook trout in lower reaches of this watershed are unclear, it is necessary that an effective suppression program be initiated. Despite capturing only around 100 age 1+ brook trout annually in lower Evans Creek over the last two years, which translates to a density of over 6 fish/100 m, a value substantially less than that documented during the first couple years of suppression in the Benewah watershed, the fact that over 760 age-0 fish were removed in 2019, representing a three-fold increase in this age class over prior years, indicates that suppression tactics have been ineffective in curbing reproduction. Though production could be coming from upstream, surveys conducted in prior years have found comparably fewer adult brook trout in upstream reaches than in the targeted suppression area. Rather, it is more probable that the lower

0.6 rkm of mainstem habitat, which is inundated by the regulation of water elevations in Coeur d'Alene Lake, harbors adult brook trout that are not vulnerable to current removal tactics (i.e., electrofishing). Temporary barriers that impede access to spawning habitat, like those employed in the Benewah watershed, or trapping devices, like fyke nets that target upriver migrants from downstream reaches, should be introduced as a suppression tactic to check brook trout production in the lower Evans Creek watershed.

Effectiveness of northern pike suppression efforts

Adfluvial WCT that originate from the Lake Creek watershed are indeed responding favorably to the removal of northern pike in Windy Bay of Coeur d'Alene Lake. Juvenile outmigrants have been found to return to spawn at rates four times greater than those recorded over a ten year period prior to the initiation of the suppression program. The documented increase in survival has also occurred simultaneously with the lack of a response in adfluvial WCT that originate from the Benewah Creek watershed. Thus, it is highly likely that the observed increase has not been the result of a recent shift in regional climatic conditions across the basin that have promoted a more favorable rearing environment in the lake. Furthermore, the observed increase in survival rates is also likely not an artifact of tagging a greater percentage of larger outmigrants more recently, given the observed advantage size at outmigration has on probability of return. Juveniles ranging from 150-200 mm in length have collectively returned at higher rates since 2015, refuting any potential tagging bias. In addition to a higher return rate of first-time spawners, return rates of repeat spawners have also increased by more than 1.5 times since inception of the suppression program. Consistent rates of survival for both life-stages, comparable to those recently observed, are projected to rebuild the spawning population of WCT in the Lake Creek watershed.

The declining trend of over 80% in the number of northern pike removed during the spring from Windy Bay over the first four years of the suppression program suggested that the localized efforts were having a measurable impact on the pike population. However, the large number of fish encountered in the spring of 2019, which was foreshadowed by suppression results in the fall of 2018, was rather disconcerting with regards to the long-term response of pike to suppression efforts. At this time, the reasons for this sudden population expansion are unclear. It is probable that pike from other areas of the lake are re-colonizing Windy Bay, though it is difficult to explain why only small size classes of pike would be immigrating. Two years ago it was also proposed that the lack of population depletion from 2016 to 2017 could be attributed to a re-colonization process, but in this case by larger individuals given the dominance of large pike in the 2017 catch and the fact that they were considerably more abundant that year than they were collectively over the two previous years (Firehammer and Vitale 2018). The discrepancy in size classes of putative immigrants observed between 2017 and 2019 is difficult to resolve, and hence does not strongly support re-colonization as the primary factor contributing to the dramatic increase in population size recorded in 2019.

On the other hand, the results observed in 2019 could be a compensatory response in young recruits due to a reduction in both competition and cannibalism from the annual removal of larger pike from the Windy Bay population. The size of pike removed in the spring of 2019 indicates that many of the fish were likely two-year olds (e.g., Walrath et al. 2015b) produced from the 2017 spawning class. Incidentally, pike removal efforts in 2017, which were initially terminated in early April because low catch rates essentially signaled their absence, were resumed in the middle of May to discover an abundance of large pike; twenty-five percent of the total that spring were collected during this resumption of suppression activity (Firehammer and Vitale 2018). Possibly, many of these large fish spawned prior to their removal giving rise to the production observed two years later. Given that only a modest number of successful spawners could quickly rebuild a depleted pike population, suppression tactics have changed to periodically deploy nets throughout the window of spawning activity even after low catch rates trigger the cessation of earlier removal efforts. Periodic suppression efforts in the spring is also intended to reduce predation on WCT given that post-spawn adults and typically over fifty percent of juvenile outmigrants are exiting Lake Creek after April (e.g., Firehammer and Vitale 2018).

The large number of presumed 2-year old northern pike removed from Windy Bay in the spring of 2019 likely did not substantially impact WCT in years prior to their recruitment to the suppression gear. The bioenergetics study conducted by Walrath et al. (2015a) in Coeur d'Alene Lake did not find WCT in diets of one year old pike, indicating that this age class is likely not a significant predator on WCT. However, this study found WCT to comprise a substantial percent of the annual diet of two year old pike (i.e., 30%), and consequently the apparently abundant year-class of pike discovered in 2019 could have a significant impact on WCT survival if not promptly addressed. Thus, suppression opportunities afforded in the fall as well as the spring provided the additional effort required to remove individuals from this year class, for the slight shift in the size distribution toward larger fish from spring to fall suppression periods in 2019 indicated that this cohort was still relatively numerous.

The addition of fall suppression efforts also serves as a forecasting tool for the following spring suppression period as documented in the fall 2018 data which projected a large catch of small fish in the spring of 2019. Notably, the fact that less pike in smaller size classes were removed in fall periods in 2019 than in 2018 suggests that production resulting from the 2018 spawn may not be as great as that observed for the 2017 spawn. The addition of another seasonal effort, however, may not be sufficient under the current suppression regime in some years to depress pike numbers. Whereas catch rates of pike plummeted rather quickly in earlier suppression years (Firehammer and Vitale 2018), catch rates in 2019 were found to periodically rebound in the spring after temporary cessation of suppression activity, and were not found to decrease throughout fall removal efforts. Consequently, it may be necessary to augment daily effort (e.g., increase the number of deployed nets from 8 to 12) to more effectively rapidly deplete numbers of pike.

Suppression efforts in the southern end of Coeur d'Alene Lake, which commenced in 2019, were projected to be more challenging than that implemented in Windy Bay given the expanse of potential spawning habitat available to pike, their documented widespread distribution across the target area, and their level of abundance (Firehammer and Vitale 2018). To that end, 2019 efforts were a combination of exploratory sampling, using telemetry results as an informative guide, and a testing of alternative gear to increase the effectiveness of the suppression program. Spring removal efforts found several spawning centers of pike in the southern end, primarily in shallow vegetated habitats in the eastern extent of the target area, though mature fish were also captured at moderate rates in other locations (e.g., Hidden and Chatcolet lakes). Thus, unlike Windy Bay, spawning aggregations were more widespread in the southern end and consequently suppression efforts will require more logistical planning and coordination.

In addition, because of the greater abundance of most other species in the southern end than in Windy Bay, an objective of the suppression program was to minimize the incidence of bycatch to increase the efficiency of efforts and to reduce undue mortality. Spring deployments revealed that many of the large-bodies fishes were captured less frequently in variable mesh than in large mesh nets, and given that mortality rates of some of these species (e.g., largemouth bass, northern pikeminnow) were relatively elevated, exclusively using variable mesh nets in suppression efforts will minimize impacts to these fishes. Though brown bullhead and black crappie were captured at considerably greater rates with the variable mesh nets, mortality rates of these species were relatively low. Moreover, pike were captured almost twice as much in the variable than in the large mesh nets further justifying their selection as the preferred mesh type.

The fall distribution of northern pike in the southern end was vastly different than that documented in the spring. Northern pike were relatively scarce in shallow sections of the target area (e.g., eastern ends of Round and Benewah lakes), and were primarily found in the deeper waters of Benewah Lake west of the trestle, and most frequently captured off the western shore of Chatcolet Lake. Incidentally, similar results were found in the fall of 2018 when areas were sampled across the southern end to appropriately allocate radio-tags. Chatcolet and Benewah lakes will therefore serve as index areas to be sampled in the fall to generate annual catch rates of pike that can be tracked over time to evaluate the effectiveness of the suppression program. Moreover, given that concentrations of pike were seemingly limited to fewer areas in the fall than in the spring, which was corroborated by the telemetry data, fall suppression may be equally or more effective than spring efforts at depleting the population. In addition, the numbers of fish captured for most other species were considerably lower in the fall than in the spring, further justifying that supplemental netting in the fall will not incur an undue proportional impact on bycatch species.

Overall, southern end suppression efforts in 2019 removed 1409 northern pike, which likely represented 50-60% of those individuals recruitable to the gear when using population estimates generated in prior years from the angler research reward program (Firehammer and Vitale 2018). In addition, it is likely than many of the larger spawners were removed in the spring given that a lower percentage of large pike were captured in the fall. However, this may be an artifact of the nets used in both seasons for large mesh nets, which were found to capture larger size classes of pike at greater rates than variable mesh nets, were not deployed in the fall. Though an apparently high percentage of the pike population was removed, considerably more effort will need to be devoted in future years to sufficiently depress pike numbers; catch rates of pike in nets that were repeatedly deployed in the same general area in Chatcolet Lake in the fall were not found to decline, signaling a lack of measurable depletion.

The telemetry results obtained during the spring of 2019 indicated that locations outside of the currently targeted suppression area likely served as important spawning centers. Approximately 30% of the radio-tagged northern pike that were actively tracked in the spring moved out of the lake upon ice-out and ascended the St. Joe River. Many of these fish accessed Hepton Lake, a shallow vegetated backwater comparable in acreage to the southern end of the lake that is annually flooded in the spring due to a connection with the St. Joe River. This large backwater likely provides valuable spawning and early life-history nursery habitat, and thus probably serves as a major source of pike production and consequently colonists for both the lower river and the lake. Currently, plans are being developed to repair the breach that allows Hepton Lake to be connected to the river to limit its ability to be accessed by adult pike in the spring.

Virtually all of the radio-tagged pike that engaged in spring spawning migrations to access backwaters and sloughs up the St. Joe River were found thereafter to return to the lake. Thus, even though there was an apparent preference of riverine habitats for spawning for some fish, there was a proclivity to return to the lake for feeding and likely overwintering. Pike found to make these seasonal migrations, though not vulnerable to spring suppression efforts in the southern end, will still be targeted by fall suppression efforts, and in this manner sources of production in habitats upriver should be depleted over time. However, it is unknown whether a sub-population of pike resides year-round in the St. Joe River that would not be susceptible to the current suppression regime. Radio-tagging pike in riverine habitats during the summer and tracking their seasonal movements may elucidate if such life-history behaviors exist.

4.2 Status and trend of westslope cutthroat trout populations

In the past, migrant traps in both Lake and Benewah creeks were used as monitoring tools to track the status and trend in metrics of adfluvial WCT production (i.e., spawners and juvenile outmigrants) at the watershed scale to aid in identifying potential factors limiting population recovery. Currently, with the advent of northern pike suppression in Coeur d'Alene Lake, this monitoring method should be viewed more appropriately under the guise of effectiveness monitoring to evaluate the response of WCT to these removal efforts. Indeed, the most recent estimate of almost 500 spawners ascending Lake Creek in the spring of 2019 is most certainly due to an increase in the survival of WCT during lake residence from the annual removal of pike, a fact supported by the recent marked increase in return rates of tagged outmigrating juveniles. The manifestation of the spawner response to the suppression program, however, was not only contingent upon in-lake survival rates, but also dependent on the number of juveniles leaving the watershed. For example, though over 4% of outmigrants from the 2016 cohort were found to return by 2018, the relatively modest spawner estimate of 230 fish in that year was likely due to the meager number of juveniles that left in 2016 when compared with earlier years. Thus, juvenile outmigrant traps are just as valuable as adult traps in providing data that facilitate the interpretation of responses, or lack thereof, to recovery actions.

Juvenile outmigrant traps are also the preferred method for marking fish that serve in effectiveness monitoring for tracking changes in return rates from northern pike suppression efforts. First, compared with tagging fish during summer stream surveys, oumigrant traps capture fish as they are leaving the watershed in the spring, thereby circumventing the inclusion of in-stream mortality rates that could confound analyses. Second, the migrant traps operated in Benewah and Lake creeks capture large numbers of fish in a relatively short period of time thereby providing the sample sizes necessary for robust evaluation. Outmigrant estimates generated from traps will also serve to assess in-stream carrying capacity as more adfluvial adults return to these watersheds. Generally, trend data from both watersheds indicated that large year classes of spawners produced sizable numbers of outmigrants two years later, implying that the current capacity of spawning and rearing habitat in both systems is under-seeded and has the capability of supporting greater numbers of migratory juveniles than what is typically observed in most years. This also suggests that populations can rebound from a depressed state, like that found in the Benewah watershed, if limiting factors (e.g., northern pike) that are inhibiting the return of migratory spawners are addressed. However, this also stresses the need for expedience in addressing these limiting factors, for a prolonged series of weak year classes of spawners that in turn produce low numbers and a less robust spatial distribution of juveniles decreases the overall resilience of the adfluvial population and renders it more vulnerable to stochastic processes within stream environments.

Stream surveys that generate density indices of salmonids in watersheds of the Coeur d'Alene basin can also be viewed contemporarily as an effectiveness monitoring tool to evaluate responses of WCT at the sub-drainage scale to recovery actions. In the past, these surveys much like migrant traps generated data that served in status and trend monitoring evaluations to identify core areas of WCT production that needed to be protected, and to identify low density reaches where associated localized deficiencies or impairments in stream conditions were prioritized for prospective habitat improvements. More recently, however, stream surveys in some watersheds are serving to evaluate the effectiveness of localized brook trout suppression programs. For example, in Benewah and Evans creeks, density indices of both WCT and brook trout are being analyzed in untreated reaches of both watersheds to evaluate their response to brook trout removal efforts in downstream habitats.

Furthermore, as pike suppression ramps up over time in the southern end of the lake, stream surveys in sub-drainages of the upper Benewah watershed will serve to evaluate the numerical response of WCT to these efforts. It is expected that greater numbers of large, fecund adfluvial adults returning to the Benewah watershed over time should increase the production and densities of WCT. In addition, the resilience of sub-drainages to periodic severe water years that induce taxing conditions during stream residence, like those projected under climate change scenarios (Barnett et al. 2005; Luce and Holden 2009), should also increase due to the availability of an adfluvial 'reserve' in the lake.

The Windfall sub-drainage serves as a testament to the lack of resilience currently found in the upper Benewah watershed. Surveys conducted during the reporting period indicated that WCT in this sub-drainage have not yet recovered from the extreme hydrologic conditions that developed during 2015. Exceptionally low spring snowpack levels that year translated to a reduction in summer flows (Mote et al. 2016), and in conjunction with elevated air temperatures and lack of precipitation throughout the summer, contributed to a depletion in the availability and quality of summer rearing habitats for WCT. Indeed, extensive stream reaches in core areas of WCT production in Windfall were found to de-water in the summer of 2015, which not only impacted age 1+ fish that year but also likely impacted fry emergence and survival rates of less mobile age-0 fish, which was manifested in the further decline of fish densities the following year. As an example, whereas the percentage of WCT that comprised fish less than 125 mm ranged from 59-66% in stream surveys conducted in Schoolhouse, SFB, and WFB sub-drainages in 2016, only 38% of the captured fish in Windfall was of this size class. Notably, percentages of WCT in this size range averaged 80% in prior survey years in the Windfall sub-drainage.

Compared with other sub-drainages in the upper Benewah watershed, the Windfall sub-drainage has been found to be primarily an adfluvial stream, as attested by its frequent selection by adfluvial spawners and the relatively greater rates of outmigration that have been detected in juveniles tagged across its stream reaches (Firehammer and Vitale 2018). Furthermore, the size distribution of WCT captured during stream surveys in Windfall, in which 96% of fish on average have been less than 150 mm in length, reflect a distribution of mostly juvenile fish, and is comparable to that documented in the Bozard sub-drainage of the Lake Creek watershed, a highly adfluvial stream (Figure B-1). Large resident-type adults, like that present in the SFB and Schoolhouse sub-drainages (Figure B-1), are lacking in Windfall and thus are not available to rapidly re-populate reaches after a severe water year. Increasing the prevalence of adfluvial adults in the upper Benewah watershed should permit this sub-drainage to more quickly rebound from an exacerbated state.

The PIT-tagging of juveniles during summer stream surveys since 2013, in addition to the tagging of ascending spawners in the spring, has provided a more detailed depiction of the status of the spatial distribution of the adfluvial life-history variant in the Benewah and Lake creek watersheds. Moreover, these data have permitted a closer examination of potential impediments that may be limiting adfluvial production in some sub-drainages. For example, additional data collected at a culvert in the UFL sub-drainage revealed that current velocities at this structure likely obstruct the ascension of adfluvial adults in most years. Given that much of the available spawning substrate in this sub-drainage exists upstream of this culvert, this apparent barrier may have substantially depressed adfluvial juvenile production over time. Because fidelity in the Lake Creek watershed has been shown to be strong in this and prior reporting periods, this may be the reason why few tagged adfluvial adults have selected this sub-drainage during their spring spawning ascensions (Firehammer and Vitale 2018). Moreover, rates of outmigration detected in juveniles tagged in the UFL during this reporting period were substantially lower than those generated for other adfluvial sub-drainages (e.g., Bozard Creek).

This culvert was replaced in 2018 and consequently the continued tagging of adfluvial fish in future years could be viewed as an effectiveness monitoring strategy to evaluate the rate of re-colonization by the adfluvial component. The observed fidelity of adults in repeat migrations, however, suggests that the re-establishment of the adfluvial variant could proceed slowly. Assuming that homing mechanisms are developed later on during stream residence, the transfer of age-0 WCT from known core production zones in adfluvial sub-drainages to reaches in the UFL sub-drainage could be a viable strategy for jump-starting the process. Bozard creek has consistently been shown in this and prior reporting periods (e.g., Firehammer and Vitale 2018) to be the primary adfluvial sub-drainage in the upper Lake Creek watershed, and due to the high density of age-0 fish documented in its reaches and its close proximity to the UFL sub-drainage, the collection and movement of young fish from Bozard to UFL reaches should not be too time-consuming or taxing on transported fish. Alternatively, permitting straying by adfluvial adults to naturally occur over time may be a less complicated venture. Notably, eight to eleven percent of adfluvial spawners ascended the UFL sub-drainage during the reporting period, a much greater amount than the two to four percent that were found to ascend from 2014 to 2017 (Firehammer and Vitale 2018).

Tagging of juvenile WCT during summer stream surveys has also permitted an examination of seasonal movements and growth rates during spring outmigration periods, which in turn has led to the identification of prospective reaches for habitat improvement projects. For example, growth rates of juvenile fish tagged during summer periods in the UFL sub-drainage that outmigrated later in the spring were greater than those for fish that left during earlier periods. Similar findings for outmigrants in the upper Lake Creek watershed have also been documented during prior reporting periods (Firehammer et al. 2016; Firehammer and Vitale 2018). Delaying downstream movement to permit additional growing opportunities may be an adaptation to increase survival rates, and apparently may be the reason that a high percentage of juvenile WCT in Lake Creek have consistently not been found to outmigrate until the middle of May under declining levels of discharge. Juvenile return data in the Lake creek watershed has shown that larger outmigrants return to spawn at much greater rates than smaller ones. Similar relationships between delayed outmigration and growth rate, whereby fish temporarily utilized low-velocity reaches for apparent feeding opportunities, have been documented for anadromous salmonids (Sommer et al. 2001).

Juvenile WCT tagged in the UFL sub-drainage that outmigrated the following spring, however, did not exhibit the behavior that has been documented in prior reporting periods by fish tagged in the Bozard sub-drainage. Fish originating from the Bozard sub-drainage have been found to exit Bozard creek in early spring, and then in lieu of sustained downstream movement, like that observed in UFL-tagged fish, they have temporarily ascended other sub-drainages, where they have spent an extended period of time prior to eventually outmigrating (Firehammer et al. 2016; Firehammer and Vitale 2018). The reason why this behavior has been exhibited by fish outmigrating from Bozard creek, and not from fish leaving other sub-drainages is not well understood. Possibly, low-velocity refuge habitat, that would support temporary feeding habitats, may not be adequately available in this sub-drainage, resulting in juveniles being displaced under periods of high spring discharge.

Aerial flights by drones have recently been conducted in reaches of both Bozard and UFL sub-drainages to illustrate the availability of potential refuge habitats during spring outmigration periods. Reaches in the UFL sub-drainage reflected a more anastomosing channel form, with more abundant side-channel habitat, than that depicted in the Bozard sub-drainage. Side-channels likely provide low-velocity areas during high flow periods that serve as energetically efficient feeding zones for fish. Because these seasonal, spring habitats have been hypothesized to be valuable in promoting growth during the spring, which in turn would favor increased survival in the lake, habitat restoration projects that re-create these conditions are currently being prioritized across suitable reaches that would benefit outmigrating WCT.

5.0 ACKNOWLEDGMENTS

The authors would like to thank Tribal elder Felix Aripa for providing inspiration and guidance that continues to motivate staff to identify and address those factors that are inhibiting recovery of culturally-important fish species like westslope cutthroat trout. Special thanks goes to the field staff - Bryan Harper, Eric Hendrickson, Jason Smith, Mark Stanger, Gene James, Glen Lambert and Todd Johnson – for without their help these data would not have been collected. Daniel Jolibois was instrumental in providing guidance to the field staff, and more importantly, the time he spent in constructing and modifying monitoring infra-structure was invaluable and provided our program with the capacity to effectively collect these data. We'd also like to thank Phyllis Johnson for ensuring that requests for equipment and materials were processed in a timely manner so that we were able to accomplish our monitoring activities. Lastly, we would like to thank the Coeur d'Alene Tribal Council and members of the Natural Resources Committee for their review, comments and support which has improved the project immeasurably. Additional funding and cost share support for this work has been provided through the Bureau of Indian Affairs. Lim lemtsh!

6.0 REFERENCES

Barnett, T.P., J.C. Adam, and D.P. Lettenmaier. 2005. Potential impacts of a warming climate on water availability in snow-dominated regions. Nature 438: 303-309.

Benjamin, J.R., J.B. Dunham, and M.R. Dare. 2007. Invasion by nonnative brook trout in Panther Creek, Idaho: roles of local habitat quality, biotic resistance, and connectivity to source habitats. Transactions of the American Fisheries Society 136: 875-888.

Bradford, M.J., J. Korman, and P.S. Higgins. 2005. Using confidence intervals to estimate the response of salmon populations (*Oncorhynchus* spp.) to experimental habitat alterations. Canadian Journal of Fisheries and Aquatic Sciences 62: 2716-2726.

Carlson, S.R., G.L. Coggins Jr. and C.O. Swanton. 1998. A simple stratified design for mark-recapture estimation of salmon smolt abundance. Alaska Fishery Research Bulletin 5 (2) 88-102.

Chapman, D. G. 1951. Some properties of the hypergeometric distribution with applications to zoological sample censuses. University of California Publications in Statistics 1: 131-160.

Chisholm, I.M., W.A. Hubert, and T.A. Wesche. 1987. Winter stream conditions and use of habitat by brook trout in high-elevation Wyoming streams. Transactions of the American Fisheries Society 116: 176-184.

Connolly, P.J., I.G. Jezorek, K.D. Martens, and E.F. Prentice. 2008. Measuring the performance of two stationary interrogation systems for detecting downstream and upsteam movement of PIT-tagged salmonids. North American Journal of Fisheries Management 28: 402-417.

Cunjak, R.A. 1996. Winter habitat of selected stream fishes and potential impacts from land-use activity. Canadian Journal of Fisheries and Aquatic Sciences 53 (Suppl. 1): 267-282.

Firehammer, J.A., A.J. Vitale, and S.A. Hallock. 2016. Implementation of fisheries enhancement opportunities on the Coeur d'Alene Reservation. 1/1/2013 – 12/31/2014 Annual Report, Project # 1990-044-00. U.S. Department of Energy, Bonneville Power Administration, Portland, OR.

Firehammer, J.A. and A.J. Vitale. 2018. Implementation of fisheries enhancement opportunities on the Coeur d'Alene Reservation. 1/1/2015 – 12/31/2017 Annual Report, Project # 1990-044-00. U.S. Department of Energy, Bonneville Power Administration, Portland, OR.

Gresswell, R.E., W.J. Liss, and G.L. Larson. 1994. Life-history organization of Yellowstone cutthroat trout (*Oncorhynchus clarki bouvieri*) in Yellowstone Lake. Canadian Journal of Fisheries and Aquatic Sciences 51 (Supplement 1): 298-309.

Griffith, J.S. 1988. Review of competition between cutthroat trout and other salmonids. Pages 134-140 *in* R.E. Gresswell, editor. Status and management of interior stocks of cutthroat trout. American Fisheries Society, Symposium 4, Bethesda, Maryland.

Huston, J.E., P. Hamlin, and B. May. 1984. Lake Koocanusa investigations final report. Montana Department of Fish, Wildlife and Parks, Helena, MT.

Lillengreen, K.L., T. Skillingstad, and A.T. Scholz. 1993. Fisheries habitat evaluation on tributaries of the Coeur d'Alene Indian Reservation. Bonneville Power Administration, Division of Fish and Wildlife, Portland Or. Project # 90-44. 218p

Lindstrom, J.W. and W.A. Hubert. 2004. Ice processes affect habitat use and movements of adult cutthroat trout and brook trout in a Wyoming foothills stream. North American Journal of Fisheries Management 24: 1341-1352.

Luce, C.H. and Z.A. Holden. 2009. Declining annual streamflow distributions in the Pacific Northwest United States, 1948-2006. Geophysical Research Letters 36 (L16401): 1-6.

Mallet, J. 1969. The Coeur d'Alene Lake fishery. Idaho Wildlife Review. May-June, 1969. 3-6 p.

Meyer, K.A., J.A. Lamansky, Jr., and D.J. Schill. 2006. Evaluation of an unsuccessful brook trout electrofishing removal project in a small Rocky Mountain stream. North American Journal of Fisheries Management 26: 849-860.

Mote, P.W., D.E. Rupp, S. Li, D.J. Sharp, F. Otto, P.F. Uhe, M. Xiao, D.P. Lettenmaier, H. Cullen, and M.R. Allen. 2016. Perspectives on the causes of exceptionally low 2015 snowpack in the western United States. Geophysical Research Letters 43: 10980-10988. doi: 10.1002/2016GL069965.

Peterson, D.P. and K.D. Fausch. 2003. Upstream movement by non-native brook trout (*Salvelinus fontinalis*) promotes invasion of native cutthroat trout (*Oncorhynchus clarki*) habitat. Can. J. Fish. Aquat. Sci. 60:1502-1516.

Peterson, D.P., K.D. Fausch, and G.C. White. 2004. Population ecology of an invasion: effects of brook trout on native cutthroat trout. Ecological Applications 14(3): 754-772.

Peterson, D.P., B.E. Rieman, J.B. Dunham, K.D. Fausch, and M.K. Young. 2008. Analysis of trade-offs between threats of invasion by nonnative brook trout (*Salvelinus fontinalis*) and intentional isolation for native westslope cutthroat trout (*Oncorhynchus clarkii lewisi*). Canadian Journal of Fisheries and Aquatic Sciences 65: 557-573.

Scholz, A.T., D.R. Geist, and J.K. Uehara. 1985. Feasibility report on restoration of Coeur d'Alene Tribal Fisheries. Upper Columbia United Tribes Fisheries Center. Cheney, WA. 85 pp.

Shepard, B.B. 2004. Factors that may be influencing nonnative brook trout invasion and their displacement of native westslope cutthroat trout in three adjacent southwestern Montana streams. North American Journal of Fisheries Management 24:1088-1100.

Sommer, T.R., M.L. Nobriga, W.C. Harrell, W. Batham, and W.J. Kimmerer. 2001. Floodplain rearing of juvenile chinook salmon: evidence of enhanced growth and survival. Canadian Journal of Fisheries and Aquatic Sciences 58: 325-333.

Stapp, P. and G.D. Hayward. 2002. Effects of an introduced piscivore on native trout: insights from a demographic model. Biological Invasions 4: 299-316.

U.S. Forest Service. 1998. Biological assessment: St. Joe River Basin/North Fork Clearwater. U.S. Fish and Wildlife Service, bull trout Section 7(a)2 consultation. 145p.

Walrath, J.D., M.C. Quist, and J.A. Firehammer. 2015a. Trophic ecology of nonnative northern pike and their effect on conservation of native westslope cutthroat trout. North American Journal of Fisheries Management 35: 158-177.

Walrath, J.D., M.C. Quist, and J.A. Firehammer. 2015b. Population structure and dynamics of northern pike and smallmouth bass in Coeur d'Alene Lake, Idaho. Northwest Science 89(3): 280-296.

Wenger, S. J., and eleven others. 2011. Flow regime, temperature, and biotic interactions drive differential declines of trout species under climate change. Proceedings of the National Academy of Sciences 108(34): 14175-14180.

7.0 APPENDICES

Appendix A – Equations for calculating WCT adfluvial abundance metrics

Adfluvial spawner abundance

The following equation was used to annually estimate the number of ascending adults in both watersheds:

$$N = \frac{(M+1)(C+1)}{(R+1)} - 1;$$

where:

N= the abundance estimate;
M= number of marked adults*;*
C= number of adults captured; and
R= number of marked adults recaptured.

The variance estimate of N was calculated as follows:

$$v(N) = \frac{(M+1)(C+1)(M-R)(C-R)}{(R+1)^2(R+2)}.$$

An approximate 95% confidence interval was then calculated as $N \pm 1.96\sqrt{v(N)}$.

Adfluvial juvenile outmigrant abundance obtained using release trials

The number of juveniles moving downstream during each release trial period was calculated using the following equation:

$$U_h = \frac{(u_h)(M_h+1)}{m_h+1},$$

where:

U_h = outmigrant abundance, excluding recaptured fish, in trial period *h*;
u_h = number of untagged fish in trial period *h;*
M_h = number of tagged fish available for recapture in trial period *h*; and
m_h = number of tagged fish recaptured in trial period *h*.

The variance estimate of U_h was calculated as follows:

$$v(U_h) = \frac{(M_h+1)(u_h+m_h+1)(M_h-m_h)(u_h)}{(m_h+1)^2(m_h+2)}.$$

Total outmigration abundance (U) and variance ($v(U)$) were then calculated as the sum of the respective estimates across all trial periods. An approximate 95% confidence interval was then calculated as:

$U \pm 1.96\sqrt{v(U)}$.

Appendix B – Supplemental tables and figures to support analyses

Table B-1. Detection efficiencies generated for PIT arrays in the upper Benewah Creek and Lake Creek watersheds in 2018. Direct efficiencies were calculated from fish detected upriver of the array that were interrogated afterwards downstream of the array, and indirect efficiencies were computed using the methodology described by Connolly et al (2008).

	2018			
	Direct Method		Indirect Method	
Location (River Km)	**Fish**	**Efficiency**	**Fish**	**Efficiency**
Upper Lake Creek watershed				
Lake creek mainstem (7.8) [a]	506	0.89	.	.
Bozard sub-drainage (13.4)	88	0.99	107	1.00
West Fork Lake sub-drainage (13.8)	17	1.00	27	1.00
Upper Fork Lake sub-drainage (13.8)	10	1.00	20	1.00
Upper Benewah Creek watershed				
Benewah creek mainstem, 9-mile (14.3)	78	0.90	173	0.96

[a] Only one antenna operable so efficiency using the indirect method could not be calculated

Table B-2. Trap efficiency trials conducted in the Benewah and Lake creek watersheds during periods of juvenile outmigration in 2018.

Benewah Creek			Lake Creek		
Trial period	**Fish released**	**Trap efficiency**	**Trial period**	**Fish released**	**Trap efficiency**
26-Mar − 02-Apr	11	0.60	03-Apr − 11-Apr	9	0.66
02-Apr − 05-Apr	13	0.56	11-Apr − 18-Apr	9	0.29
05-Apr − 09-Apr	15	0.68	18-Apr − 30-Apr	58	0.28
09-Apr − 11-Apr	24	0.37	30-Apr − 02-May	32	0.30
11-Apr − 13-Apr	11	0.57	02-May − 04-May	34	0.20
13-Apr − 16-Apr	11	0.27	04-May − 07-May	31	0.22
16-Apr − 19-Apr	13	0.21	07-May − 09-May	31	0.37
19-Apr − 23-Apr	7	0.74	09-May − 11-May	29	0.43
23-Apr − 26-Apr	23	0.45	11-May − 14-May	30	0.58
26-Apr − 30-Apr	14	0.46	14-May − 16-May	30	0.58
30-Apr − 04-May	13	0.41	16-May − 18-May	30	0.76
04-May − 11-May	31	0.30	18-May − 21-May	30	0.58
11-May − 21-May	9	0.18	21-May − 23-May	30	0.35
			23-May − 25-May	31	0.41
			25-May − 27-May	30	0.26
			27-May − 30-May	30	0.08
			30-May − 01-Jun	10	0.54
			01-Jun − 04-Jun	4	0.35

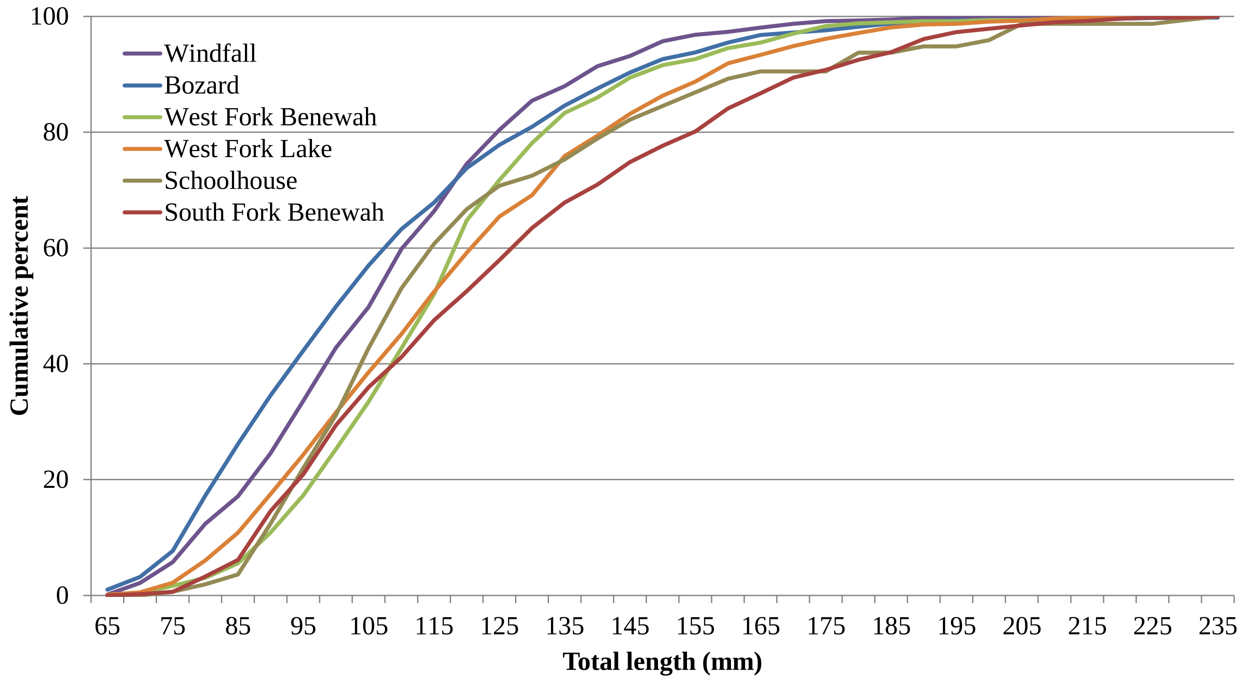


Figure B-1. Cumulative distribution of total length (mm) of WCT captured in stream surveys in the Windfall, West Fork Benewah, South Fork Benewah, and Schoolhouse sub-drainages in the upper Benewah watershed, and the Bozard and West Fork Lake sub-drainages in the upper Lake watershed, 2013-2015.

Appendix C – Photos of monitoring sites and equipment

Photo 1. Floating weir trap used in Lake Creek to intercept adfluvial WCT adults. Pictured on the left is the series of interconnected picket panels that are supported underneath by a structure that can be manually raised or lowered. Pictured on the right is the winch that is used to adjust the panels, and the livebox for holding captured fish

Photo 2. The rotary screw trap used in Lake Creek to intercept adfluvial WCT juvenile outmigrants.